U. S. Fish and Wildlife Service

Report to the
U.S. Environmental Protection Agency
for the
Bristol Bay Watershed Assessment

Wildlife Resources of the
Nushagak and Kvichak River Watersheds

External Review Draft

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EXECUTIVE SUMMARY

Background

At the request of the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS) prepared this report which summarizes known information related to brown bear, moose, caribou, wolf, waterfowl, bald eagle, shorebirds, and landbirds in the Bristol Bay region of Alaska, with a focus on the Nushagak and Kvichak watersheds. These species were selected for review because of their importance to ecosystem function, their direct link to salmon, or their importance to local and Alaska residents. EPA is conducting a watershed assessment in the Nushagak and Kvichak watersheds in response to requests from various organizations under the authority of the Clean Water Act, and requested assistance from the USFWS, as the agency with responsibilities and expertise for the nation's fish and wildlife resources. This report is a small portion of the larger EPA effort which includes evaluation of fish resources of the region, hydrology, and an ecological risk assessment related to potential effects of large scale mineral development on fish, wildlife, water quality, and humans. In addition to being part of the EPA Bristol Bay Watershed Assessment, the information in this report will be useful for Statewide or regional land use planning, completion of environmental documentation for permitting of development projects, or activities related to Landscape Conservation Cooperatives in Alaska.

In this report, we describe: habitat use; food habits; behavior; interspecies interactions; productivity, mortality and survivorship; populations, subpopulations, and genetics; human use and interactions, and management for wildlife with a focus on the Nushagak and Kvichak watersheds, to the extent that existing data allow. We describe the relationship of these wildlife species (brown bear, moose, caribou, wolf, and bald eagle) or species guilds (waterfowl, shorebirds and landbirds) with salmon. We describe the dependence of wildlife on marine derived nutrients (MDN) transported to these watersheds by salmon and the role of wildlife in distributing MDN through the ecosystem to the extent this information is available.

About 40 current or retired biologists and scientists from USFWS, National Park Service, Bureau of Land Management, U.S. Geological Survey, U.S. Forest Service, and Alaska Department of Fish and Game were involved with preparation and review of this report. Collectively, these biologists and scientists have significant experience with research and management of wildlife in Alaska and many have extensive experience in the Nushagak and Kvichak watersheds.

The Importance of Marine-Derived Nutrients to Bristol Bay

One of the most important ecological functions of salmon is to transfer large quantities of nutrients from the marine environment into terrestrial and freshwater ecosystems within the watersheds where adults return to spawn. Marine-derived nutrients (MDN), in combination with other ecosystem features such as suitable spawning habitat and oceanic carrying capacity, are essential for the survival and growth of the next generation of salmon, and also greatly benefit other fish and wildlife species. Herbivores benefit from increased vegetative growth in riparian areas stimulated by MDN, while carnivores and scavengers directly consume migrating salmon or their carcasses. In both aquatic and terrestrial ecosystems, MDN are also integrated into the base of food chains, and increased productivity is transferred to species at higher trophic levels. It is likely that southwest Alaska and the Nushagak and Kvichak watersheds support large

populations of wildlife both because habitat in the region is almost totally intact and because of the presence of millions of salmon annually spawning, rearing, and migrating to sea and back. The annual introduction of millions of pounds of MDN from salmon and the lack of significant anthropogenic watershed disturbances make Bristol Bay relatively unique in the world.

Brown bears within the Nushagak and Kvichak watersheds depend on salmon for food and survival. Accumulation of fat reserves is important for successful hibernation, and for female reproductive success. Wolves also consume salmon seasonally when available, and this marine-derived source of food is a major component of the lifetime total diet of wolves in areas where the two species co-exist. Brown bears and wolves play an important role in distributing MDN from streams to the terrestrial environment, both by transporting salmon carcasses prior to consumption and through excretion of wastes rich in salmon nutrients. Both brown bears and wolves have been documented travelling long distances to feed on salmon.

Waterfowl benefit from salmon which provide a large influx of nutrients to riverine and terrestrial systems, both directly as sources of prey and carrion, and indirectly as nutrient drivers of aquatic systems. Of the 24 duck species that regularly occur in Bristol Bay, at least eleven species are known to prey on salmon eggs, parr, smolts, and scavenge on carcasses. Of these, greater and lesser scaup, harlequin duck, bufflehead, common and Barrow's goldeneyes, and common and red-breasted mergansers exhibit directed foraging on salmon. Among dabbling ducks, mallards feed most on salmon because they are distributed across a diversity of summer habitats in spawning areas, and they are the principal wintering dabbling duck on the North Pacific coast where fall-winter salmon runs occur. Fish predators like mergansers feed extensively on salmon fry and smolts. Other duck species may prey on smolt incidentally. Salmon eggs are a seasonally rich food source for harlequin ducks, goldeneyes and scaup that frequent rivers and streams and probably for other opportunistic ducks. Species ranging from dabbling ducks (mallard, green-winged teal) and diving ducks to sea ducks that inhabit spawning waters probably opportunistically scavenge easy protein-rich meals from salmon carcasses.

Spawned-out salmon carcasses provide an ideal food resource to bald eagles. The abundance of salmon in the region affects bald eagle population size, distribution, breeding and behavior. In one studied population, salmon availability in spring was tightly correlated with whether adult bald eagles laid eggs in a given year, and also influenced the timing of egg-laying. As with other salmon consumers, bald eagles affect the ecosystems within their range by distributing MDNs in their excretions.

Direct or indirect interactions between shorebirds and salmon are not well-documented. Some shorebird species are observed to consume dead salmon and salmon eggs. No studies have been conducted to deduce the contribution of salmon to the energetics of shorebird populations; however, the abundance of invertebrates in the intertidal zone is very likely due in part to MDN from salmon that die on the coast and in the rivers feeding Bristol Bay. Shorebirds play a role in distributing MDNs into the terrestrial system, especially during the migratory period, but this has not been quantified. Some of the longest migrations known for birds involve shorebird species (bar-tailed godwit) that use Bristol Bay intertidal areas in autumn. Such flights are possible not only due to the extreme abundance of intertidal invertebrates (polychaetes, crustaceans, gastropods, and bivalves) in the region, but also because the adjacent uplands are usually rich in

fruits of ericaceous plants or tubers that birds like plovers, whimbrels, and godwits, regularly feed on. Some species like whimbrel, Hudsonian godwit, and black and ruddy turnstones feed on herring roe, carrion (including salmon carcasses), and salmon eggs. Many shorebirds make use of freshwater invertebrates; small fish may be consumed by yellowlegs and phalaropes.

Landbirds also benefit from salmon carcasses when available. Aquatic invertebrate larvae feed on salmon carcasses, overwinter in the soil, and emerge in the spring as adults. These invertebrate adults become prey for a variety of landbird species in the spring, and serve as an important seasonal subsidy during a period when terrestrial invertebrate biomass is low. Salmon also benefit landbirds by increasing plant productivity due to MDN inputs, potentially resulting in an abundance of berries and seeds for avian consumption. Some birds, such as the American Dipper, directly consume salmon eggs, fry, and small bits of carcasses when available.

In summary, MDN from salmon cycle throughout the ecosystem of watersheds with healthy salmon runs, benefitting wildlife, increasing vegetation productivity, and promoting the production of periphyton, aquatic macroinvertebrates, resident freshwater fish, and juvenile salmon. This nutrient cycling is in turn dependent on interactions with wildlife, which distribute MDN into the terrestrial environment through both transport of carcasses and excretion of wastes. The loss of either salmon or key wildlife species may result in significant changes to the productivity, diversity and physical structure of the ecosystem, via mechanisms that extend beyond simple "food chain" interactions.

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INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is conducting a watershed assessment in the Nushagak and Kvichak River watersheds of Bristol Bay, Alaska in response to requests from nine Tribal Governments and other interests. The tribes have requested that EPA take action to protect the Bristol Bay watershed from the adverse impacts of potential large-scale hard rock mining projects utilizing EPA's statutory authority, including Section 404(c) of the Clean Water Act (CWA). Section 404(c) allows EPA to prohibit or restrict discharges of dredged or fill material into waters of the United States, including wetlands, when it determines that such discharges would have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas. EPA has also received requests from two tribes and other interests to refrain from taking advance action and to wait for specific permit applications for mining projects to be reviewed by the U.S. Army Corps of Engineers (Corps) pursuant to Section 404 of the CWA and the National Environmental Policy Act (NEPA). EPA is conducting the Bristol Bay Watershed Assessment (BBWA) under its Clean Water Act Section 104(a) authority, which directs them to: *"...conduct and promote the coordination and acceleration of, research, investigations, experiments, training, demonstrations, surveys, and studies relating to the causes, effects, extent, prevention, reduction, and elimination of pollution."*

EPA requested that the U.S. Fish and Wildlife Service (USFWS) provide assistance in conducting the BBWA. The mission of the USFWS is to work with others to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. The USFWS works to protect a healthy environment for people, fish and wildlife, and helps Americans conserve and enjoy the outdoors and our living treasures. The USFWS has responsibility for fish and wildlife resources with specific emphasis on migratory birds, endangered plants and animals, certain marine mammals, and freshwater and anadromous fish. USFWS expects that this report will be useful to EPA in completing the BBWA, but it should also provide a comprehensive summary of wildlife information for others interested in southwest Alaska. These uses might include: completion of environmental documentation for oil and gas leasing or any development project; activities related to the Western Alaska Landscape Conservation Cooperative; the Southwest Alaska Salmon Habitat Partnership; or any land use planning effort.

The Bristol Bay watershed is comprised of six major drainages: the Togiak River, Nushagak River, Kvichak River, Naknek River, Egegik River, and Ugashik River. The Kvichak and Nushagak River watersheds are the principle Bristol Bay drainages that have lands open to large-scale development. Much of the rest of the region is within National Parks or National Wildlife Refuges and is protected from such development. EPA's analysis therefore, focuses on the Nushagak and Kvichak watersheds (Figure 1).

The objective of the BBWA process is to build a common understanding of both the fish and wildlife resources of Bristol Bay and the potential impacts to those resources from large-scale development and to identify possible options for protecting these resources. The overall assessment represents an integration of several types of evaluations. The first component is an assessment of the resources themselves, also called a characterization, which synthesizes current conditions within the Nushagak and Kvichak watersheds and compares those resources to other regional or reference areas. It's focus is determining if the resources in question, the wildlife of the

Nushagak and Kvichak watersheds in the case of this report, represent an exceptional resource that might be worthy of special protection. For exceptional resources, the characterization identifies the environmental factors that contribute to the extraordinary nature of the resource. The characterization thus identifies what must be protected to retain an exceptional status. The second component of the evaluation is a predictive risk assessment, devoted, in this case, to estimating the effects of reasonably foreseeable large-scale development in the area on wildlife. It is organized on the established EPA frameworks for ecological and cumulative risk assessments. The potential development scenarios and the results of the predictive risk assessment include inherent uncertainties and cumulative risks.
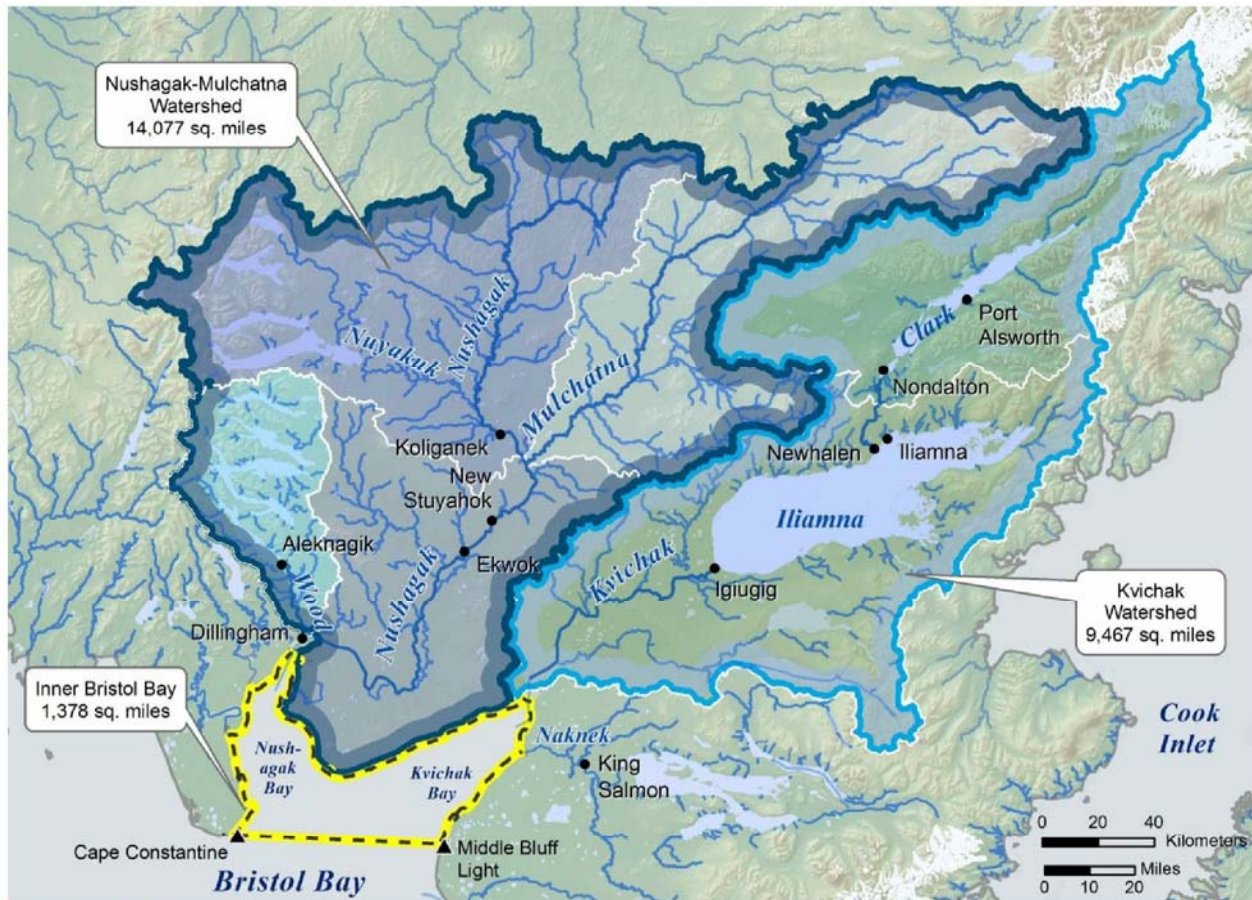
Figure 1. Nushagak and Kvichak River watersheds and inner Bristol Bay.

METHODOLOGY

There are two phases of the EPA BBWA: characterization and predictive risk assessment. Characterization is the review and documentation of relevant literature, interviews with knowledgeable agency staff and other experts on the ecological and economic significance of the fish and wildlife resources in the Nushagak and Kvichak watersheds. The goal of this review and documentation process is to describe the level of current scientific knowledge of fish and wildlife resources of Bristol Bay, and to answer the question "What is the ecological and economic significance of Bristol Bay fish and wildlife resources locally and around the North Pacific Ocean?" This USFWS report is primarily intended to provide information to EPA about wildlife resources in the Nushagak and Kvichak watersheds for their use in developing the BBWA but, it

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could also be useful for other land use planning or project environmental review and permitting activities. EPA is preparing a separate report which characterizes fish in the Bristol Bay region.

Predictive risk assessment is the review and documentation of relevant literature, interviews with knowledgeable agency staff and other experts on the risks, threats and stressors associated with current and foreseeable human activity on the health, productivity, ecological integrity, and long-term sustainability of fish and wildlife resources of Bristol Bay. It includes review and documentation of mitigation practices used to abate threats and risks to fish and wildlife resources.

Based on the scope of the BBWA, USFWS formulated three objectives for this report to EPA. These are:
1. Describe significant, representative wildlife species in Bristol Bay and their importance to humans;
2. Describe the importance of marine derived nutrients to these wildlife species; and
3. Describe the role of these wildlife species in distributing marine derived nutrients throughout the ecosystem.

Geographic Scope of USFWS Evaluation

The primary geographic scope of the BBWA, and therefore this report, is the Nushagak and Kvichak watersheds. In addition to terrestrial mammal species, the USFWS is characterizing and assessing migratory birds, many of which use marine waters during some portion of the year. Therefore, we needed to determine the extent of freshwater influence from these river systems in the Bristol Bay marine environment. Data on the hydrography of the Bay is limited; however, an evaluation based on salinity differences, drift cards and fluorescent dye (Straty, 1977), indicates that the net seaward flow of lighter and less saline river runoff water from the Kvichak River (and the adjacent Naknek River to the south) moves in a counterclockwise direction along the northwest side of inner Bristol Bay, where it mixes with water from the Nushagak River. Data indicate that the mixture of Kvichak and Naknek river water remains relatively distinct as far as Cape Constantine. On the southeast side of the bay, the answer is less clear. However, Egegik River water does not appear to travel much further north than Middle Bluff Light. North of Middle Bluff Light water immediately along the shoreline is probably mostly Naknek River water, but by around 8 km off shore, Naknek River water is mixed with Kvichak River water. Therefore, to facilitate evaluation of migratory birds in marine waters, we are defining the area of freshwater influence as the area north of a line drawn from Cape Constantine east to Middle Bluff Light. We call this area inner Bristol Bay for purposes of this report. This area is marked with the yellow dashed line on Figure 1.

Selection of Wildlife Species for Characterization

EPA asked the USFWS for assistance in evaluating wildlife species that can be directly linked to salmon, due either to their direct dependence on salmon for survival (food) or to their role in distributing marine derived nutrients throughout freshwater aquatic or terrestrial ecosystems. The vast number of wildlife species in the Nushagak and Kvichak watersheds made it impractical to characterize each individual species. Additionally, staff resources available to the USFWS and time constraints imposed by the EPA BBWA process, also meant that there would be no new primary wildlife data collection and that our analysis would be based primarily on previously-collected data.

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The first step, therefore, was to identify a subset of wildlife species that represent major components of biodiversity in the region. Initially, the USFWS decided to use portions of an approach developed by The Nature Conservancy for ecoregional planning (Groves et al., 2000). This process was modified for use by the Mat-Su Salmon Habitat Partnership to develop a Strategic Habitat Action Plan and also by The Nature Conservancy in preparing the Alaska Peninsula and Bristol Bay Basin Ecoregional Assessment (The Nature Conservancy in Alaska, 2004). A simplified version was also used by the Southwest Alaska Salmon Habitat Partnership to develop a draft Strategic Habitat Conservation Action Plan. The USFWS is a member of both fish habitat partnerships and USFWS biologists were also involved with the Ecoregional Assessment, so we are familiar with ecoregional planning concepts.

Ecoregional planning, as described by Groves et al. (2000) is a complex, step-by-step approach with the goal of selecting and designing networks of areas of high biodiversity significance (conservation sites) that will conserve the diversity of species, communities, and ecological systems in an ecoregion. Since this is not the goal of the USFWS's work as part of the EPA BBWA, we used selected portions of the approach to help us identify wildlife species targets. Species-level targets facilitate identification of threats and development of strategies and actions to abate threats.

The USFWS selected key wildlife species for our contribution to the EPA BBWA based largely on professional judgment, and consultation with EPA, and members of the BBWA Intergovernmental Technical Team. Key species regulate energy flow and nutrient dynamics or they may be ecosystem engineers that modulate habitat structure (Davic, 2003). We define key species as being those we know from experience, have a direct link to salmon or are of special interest to local or Alaska residents. Additionally, migratory birds and bald eagles are considered key species because the USFWS has direct statutory authority for them under the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act.

The term "key species" should not be confused with the term "keystone species" which are those whose impact on a community or ecological system is disproportionately large for their abundance and biomass (Paine, 1995). Keystone species have spatial, compositional and functional requirements that may encompass those of other species in the region and they may play a critical role in maintaining the structure of an ecological community. They affect many other organisms in an ecosystem and help to determine the types and numbers of various other species in the community. They contribute to ecosystem function in a unique and significant manner through their activities. Their removal may initiate changes in ecosystem structure and often a loss of diversity (e.g., beaver, bison, prairie dog). Keystone species may also be wide-ranging and depend on vast areas for survival. These species include top-level predators (e.g., wolves, grizzly bear) as well as migratory mammals (e.g., caribou), anadromous fish and birds (The Nature Conservancy in Alaska, 2004). Keystone species regulate local species diversity in lower trophic levels (Davic, 2003).

The key species the USFWS selected for inclusion in the wildlife component of the BBWA are:

- brown bear;
- moose;
- barren ground caribou;

- wolf;
- waterfowl (as a guild);
- bald eagle;
- shorebirds (as a guild); and
- landbirds (as a guild).

The USFWS also considered including species listed under the Endangered Species Act and seabirds but a preliminary assessment revealed there are no significant occurrences of either listed species or significant assemblages of seabirds in the Nushagak and Kvichak watersheds or inner Bristol Bay.

The Characterization Process

Staff from the Anchorage Fish and Wildlife Field Office (AFWFO) prepared initial drafts of all but two of the species accounts. The waterfowl species account was developed by a contractor and the shorebird account was drafted by a USFWS National Wildlife Refuge biologist. Species accounts were drafted based on a suggested outline provided by AFWFO. We circulated for review and comment initial draft species accounts to numerous experts from the USFWS, other federal and State agencies, and other knowledgeable individuals, many of whom are retired federal or State wildlife biologists. The USFWS then obtained assistance from expert wildlife biologists to revise the draft species accounts on brown bear, caribou, moose, and bald eagles. Finally, we circulated the revised draft species accounts for review and comment. A list of authors and reviewers for each species account is provided in Appendix 1. All completed species accounts are incorporated in this report.

Species accounts were largely developed using available published data and information, but in some instances we used unpublished information from species experts. Our preference was to use data specific to the Nushagak and Kvichak watersheds. However, we also used relevant information from other regions of Alaska or other parts North America.

CHARACTERIZATION OF WILDLIFE

Overview of Wildlife Species

<u>Alaska-</u> Many Alaskans depend on the State's diverse wildlife resources[1] for food and enjoyment. Traditional subsistence harvest and personal use, sport and guided hunting, as well as nonconsumptive uses of wildlife, such as wildlife viewing, are critical components of the Alaska economy and lifestyle (ADF&G, 2006). According to the Alaska Department of Fish and Game (ADF&G), the value of game species such as moose, caribou, and deer are well understood by most Alaskans(ADF&G, 2006). Historically, species not taken for subsistence, sport, or commercial use, were perceived as having little direct economic value. However, the contribution of nongame species to Alaska's economy is substantial, although difficult to quantify. According to ADF&G, basic biological information on life history, population levels, and other parameters is lacking for many species, but the majority of Alaska's wildlife resources are considered healthy.

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[1] ADF&G includes fish, reptiles, amphibians, and marine mammals (including whales) in the definition of wildlife in the Comprehensive Wildlife Strategy. Of the 1,073 vertebrate species known to occur in Alaska, there are 469 species of birds and 64 species of terrestrial mammals (ADF&G 2006; Jarrell et al 2004).

**Southwest Alaska Region-** Southwest Alaska, including the Nushagak and Kvichak watersheds, possesses intact, naturally functioning terrestrial ecosystems that still support their historic complement of species, including large carnivores. Such ecosystems, containing historic levels of biodiversity, are becoming extremely rare globally. Large terrestrial herbivore-predator interactions are an intrinsic property of intact functioning ecosystems and are a flagship ecological feature of southwest Alaska (Bennett et al., 2006; Jarrell et al., 2004; Nushagak-Mulchatna Watershed Council, 2007).

Based on a compilation of vertebrate species lists for Togiak National Wildlife Refuge (NWR) (USFWS, 2009b), Alaska Peninsula and Becharof NWR Bird List (USFWS, 2010b), and southwest Alaska national parks (Cook and MacDonald, 2005), there are 192 species of birds and 41 species of terrestrial mammals in southwest Alaska (Appendix 2). There is no comprehensive species list available for the Nushagak and Kvichak watersheds, but it is reasonable to assume that species in these watersheds are nearly identical to those in the larger region.

Of all the species described in this report, caribou, moose and waterfowl are probably the most important subsistence species to local residents. These species also provide significant recreational hunting opportunities for both nonlocal resident and nonresident hunters. Other wildlife species which provide subsistence food for local residents include black bears, beaver, ptarmigan, and porcupine. River otter, red fox, marten and wolverine are also important in the region. We have not identified any of these other wildlife species as key species for purposes of this report.

The Importance of Marine-Derived Nutrients to Bristol Bay Watershed Ecosystems

One of the most important ecological functions of salmon is to transfer large quantities of nutrients from the marine environment into terrestrial and freshwater ecosystems within the watersheds where adults return to spawn. Pacific salmon spend most of their lives feeding and growing at sea before returning to spawn and die in their natal streams or lakes, and approximately 95 to 99% of the carbon, nitrogen, and phosphorus in the adult salmon body are derived from the marine environment (Larkin and Slaney, 1997; Schindler et al., 2005). These nutrients are transported inland when salmon return to their natal streams or lakes to spawn. For oligotrophic Lake Iliamna, the annual nitrogen pool associated with the annual spawning migration is comparable in size with the dissolved nitrogen pool in the lake, indicating the importance of adult salmon to the lake's nitrogen budget (Kline et al., 1993). Marine-derived nutrients (MDN), in combination with other ecosystem features such as suitable spawning habitat and oceanic carrying capacity (Schindler et al., 2005), are essential for the survival and growth of the next generation of salmon, and also greatly benefit a number of other fish and wildlife species.

Brown bears within the Nushagak and Kvichak watersheds depend on the annual salmon runs as an excellent source of lipids. In several Alaskan brown bear populations, lipids obtained through the consumption of salmon contributed approximately 80% of the mass gained by bears prior to winter hibernation (Hilderbrand et al., 1999c). Accumulation of fat reserves is important for successful hibernation, and for female reproductive success (Farley and Robbins, 1995; Hilderbrand et al., 1999c).

Wolves also consume salmon seasonally when available, and this marine-derived protein source can be a major component of the lifetime total diet of wolves in areas where the two species co-exist (Adams et al., 2010; Darimont et al., 2003; Szepanski et al., 1999). Salmon are not solely a food resource for coastal wolves, as some Pacific salmon spawning grounds are hundreds of miles from the ocean. A study in Interior Alaska documented the seasonal salmon consumption among wolves who lived more than 1,200 river miles from the coast (Adams et al., 2010).

Both brown bears and wolves play an important role in distributing MDN from streams to the terrestrial environment, both by transporting salmon carcasses prior to consumption and through excretion of wastes rich in salmon nutrients (Darimont et al., 2003; Helfield and Naiman, 2006).

As far as we can determine, there has been no research conducted on the MDN links between salmon and moose or caribou. However, we believe that while it is reasonable to assume that MDN transported to the Nushagak and Kvichak watersheds by salmon may be detectable in tissue of animals, especially those preferentially feeding in riparian areas (e.g. moose), this does not necessarily mean there would be any detectable benefit to these herbivores. In order for there to be a direct effect, salmon would have to have a strong fertilizing effect on forage, resulting in additional biomass on the landscape, and ungulates would have to be forage limited in order for the increased biomass to matter (Adams, personal communication). There have been anecdotal reports of ungulates (both deer and moose) feeding directly on salmon carcasses (Hilderbrand, personal communication).

Waterfowl benefit from salmon as both direct sources of prey and carrion and indirect nutrient drivers of aquatic systems. The large influx of nutrients to riverine and terrestrial systems strongly benefits waterfowl (Holtgrieve, 2009; Willson et al., 1998; Willson and Halupka, 1995). Of the 24 duck species that regularly occur in Bristol Bay, at least eleven species are known to prey on salmon eggs, parr, smolts, and scavenge on carcasses (Table 9). Of these, greater and lesser scaup, harlequin duck, bufflehead, common and Barrow's goldeneyes, and common and red-breasted mergansers exhibit directed foraging on salmon. Among dabbling ducks, mallards feed most on salmon because they are distributed across a diversity of summer habitats in spawning areas, and they are the principal wintering dabbling duck on the North Pacific coast where fall-winter salmon runs occur. Fish predators like mergansers feed extensively on salmon fry and smolts (Munro and Clemens, 1932; Munro and Clemens, 1937; Munro and Clemens, 1939; Salyer and Lagler, 1940; White, 1957; Wood, 1987a). Other duck species may prey on smolt incidentally. Salmon eggs are a seasonally rich food source for harlequin ducks, goldeneyes and scaup that frequent rivers and streams (Cottam, 1939; Dzinbal and Jarvis, 1984; Munro, 1923) and probably for other opportunistic ducks. Species ranging from dabbling ducks (mallard, green-winged teal) and diving ducks to sea ducks that inhabit spawning waters probably opportunistically scavenge easy protein-rich meals from salmon carcasses.

Spawned-out salmon carcasses provide an ideal food resource to bald eagles as they accumulate on stream banks, river bars, lake and ocean shores, and tidal flats (Armstrong, 2010). Salmon carcasses may provide food to eagles beyond the spawning season, as large numbers of carcasses may be frozen into river ice during the winter and become available for consumption by eagles the following spring (Hansen et al., 1984). The abundance of salmon affects bald eagle population size, distribution, breeding and behavior (Armstrong, 2010). In one studied population, salmon availability in spring was tightly correlated with whether adult bald eagles laid eggs in a given year, and also influenced the timing of egg-laying (Hansen et al., 1984). As with other salmon

carcass consumers, bald eagles affect the ecosystems within their range by distributing MDNs in their excretions (Gende et al., 2002).

Direct or indirect interactions between shorebirds and salmon are not well-documented. Some shorebird species are observed to consume dead salmon and salmon eggs, but it is unlikely that shorebirds have an impact on salmon populations. No studies have been conducted to deduce the contribution of salmon to the energetics of shorebird populations; however, the abundance of invertebrates in the intertidal zone is very likely due in part to MDN from salmon that die on the coast and in the rivers feeding Bristol Bay. Shorebirds play a role in distributing MDNs into the terrestrial system, especially during the migratory period, but this has not been quantified. They frequently feed in the intertidal zone, but roost in the terrestrial zone, where they deposit their waste. In the spring, shorebirds need to acquire critical food resources, not only to fuel their migration, but also, for some species, to assure that they arrive on the breeding grounds with sufficient reserves to initiate nesting and egg production (Klaassen et al., 2006; Yohannes et al., 2010). Some of the longest migrations known to birds involve shorebird species (bar-tailed godwit) that use Bristol Bay intertidal areas in autumn (Battley et al., 2011; Gill et al., 2009). Such flights are possible not only due to the extreme abundance of intertidal invertebrates (polychaetes, crustaceans, gastropods, and bivalves) in the region, but also because the adjacent uplands are usually rich in fruits of ericaceous plants or tubers on which birds like plovers, whimbrels, and godwits, regularly feed (Elphick and Klima, 2002; Johnson and Connors, 1996; Paulson, 1995; Skeel and Mallory, 1996). Some species like whimbrel, Hudsonian godwit, and black and ruddy turnstones feed on herring roe, carrion, including salmon carcasses, and salmon eggs (Elphick and Tibbitts, 1998; Gill et al., 2002; Handel and Gill, 2001; Nettleship, 2000; Norton et al., 1990). Many shorebird species make use of freshwater invertebrates; small fish may be consumed by yellowlegs (Elphick and Tibbitts, 1998) and phalaropes (Rubega et al., 2000).

Landbirds also benefit from salmon carcasses when available. Aquatic invertebrate larvae feed on salmon carcasses (Wipfli et al., 1999), overwinter in the soil, and emerge in the spring as adults. These invertebrate adults become aerial prey for a variety of landbird species in the spring, and serve as an important seasonal subsidy during a period when terrestrial invertebrate biomass is low (Nakano and Murakami, 2001). Salmon also benefit landbirds by increasing plant productivity due to MDN inputs (Helfield and Naiman, 2001), potentially resulting in an abundance of berries and seeds for avian consumption (Christie and Reimchen, 2008). Some birds, such as the American Dipper, directly consume salmon eggs, fry, and small bits of carcasses when available. In one study of dippers, consumption of salmon fry was related to higher fledgling mass and lower brood reduction (Obermeyer et al., 2006).

In summary, MDN from salmon cycle throughout the ecosystem of watersheds with healthy salmon runs, benefitting wildlife, increasing vegetation productivity, and promoting the production of periphyton, aquatic macroinvertebrates, resident freshwater fish, and juvenile salmon (Helfield and Naiman, 2006). This nutrient cycling is in turn dependent on interactions with wildlife, which distribute MDN into the terrestrial environment through both transport of carcasses and excretion of wastes. The loss of either salmon or key wildlife species may result in significant changes to the productivity, diversity and physical structure of the ecosystem, via mechanisms that extend beyond simple "food chain" interactions (Helfield and Naiman, 2006).

Overview of Land Cover and Habitat Types

The National Land Cover Database (NLCD) 2001 is a Landsat-derived, 30-meter spatial resolution map that illustrates land cover for the United States, including Alaska (Homer et al., 2004) (http://alaska.usgs.gov/science/geography/nlcd.html). The NLCD dataset is a fairly broad level characterization and is the only dataset that covers the entire Nushagak and Kvichak watersheds. Therefore, we use the NLCD as a surrogate for a wildlife habitat-type map. Nineteen land cover types are described for Alaska: open water; perennial ice/ snow; developed, open space; developed, low intensity; developed, medium intensity; developed, high intensity; barren land; deciduous forest; evergreen forest; mixed forest; dwarf scrub; shrub/scrub; grassland/herbaceous; sedge/herbaceous; moss; pasture/hay; cultivated crops; woody wetlands; and emergent herbaceous wetlands (Selkowitz and Stehman, 2011; Talbot, 2010).

Figure 2 shows the land cover types present in the Nushagak and Kvichak watersheds. The NLCD does not describe wetlands in great detail and wetlands likely extend into other land cover types not specifically identified as such (e.g., sedge/herbaceous land cover, which may include wet tussock tundra, and evergreen forest, which may include wet black spruce bogs). Table 1 shows the total size of each watershed and sub-watershed, as well as the percentage of each NLCD land cover type in each.
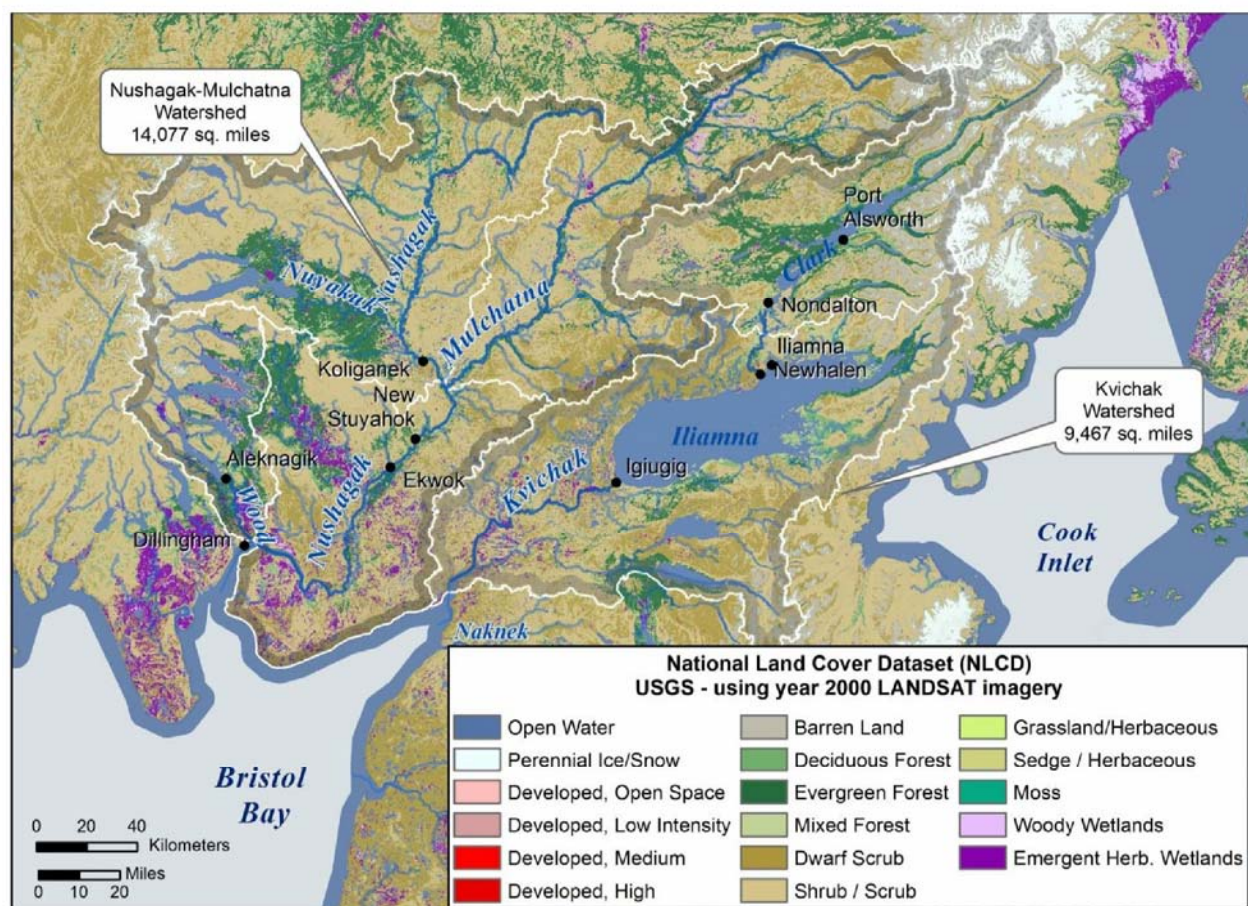
Figure 2. National Land Cover Dataset, land cover types for the Nushagak River watershed and Kvichak River watershed.

Currently, there is only one statewide ecosystem map available for Alaska (Nowacki et al., 2001). This map describes 32 ecoregional landscapes, but it is very coarse and not intended to provide specific habitat classifications for wildlife. This ecosystem map does not provide sufficient detail to be used for habitat type classification as part of this project.

Table 1. Size of subbasins (sq. mi.) within the Nushagak and Kvichak River watersheds and percent of watershed or subbasin within each National Land Cover Database land cover type.

	Kvichak River Watershed			Nushagak River Watershed					Total
	Lake Clark Subbasin	Lake Iliamna Subbasin	Sub-total	Mulchatna River Subbasin	Upper Nushagak River Subbasin	Lower Nushagak River Subbasin	Wood River Subbasin	Sub-total	
Size (Square Miles)	3,532	5,935	**9,467**	4,291	5,026	3,386	1,367	**14,077**	**23,537**
Land Cover Type	Percent of Watershed								
Open-Water	5.96	23.89	**17.20**	2.31	5.34	5.36	14.28	**5.29**	
Perennial Ice & Snow	6.51	0.38	**2.67**	0.39	1.61	0.00	1.32	**0.82**	
Developed, Low Intensity	0.02	0.01	**0.01**	0.00	0.00	0.00	0.00	**0.00**	
Barren Land	23.55	5.88	**12.47**	4.61	3.31	0.09	.36	**2.94**	
Deciduous Forest	2.92	2.79	**2.84**	1.94	3.63	2.15	4.36	**2.83**	
Evergreen Forest	15.51	5.34	**9.13**	10.04	11.86	9.63	13.81	**10.96**	
Mixed Forrest	4.45	3.20	**3.67**	2.30	5.08	2.99	5.47	**3.77**	
Dwarf Scrub	10.85	22.57	**18.19**	24.50	12.77	20.06	5.26	**17.24**	
Shrub Scrub	28.27	31.79	**30.66**	51.08	54.97	44.86	44.12	**50.23**	
Sedge Herbaceous	0.01	1.67	**1.05**	0.48	0.37	3.86	0.13	**1.22**	
Moss	0.01	0.02	**0.01**	0.00	0.02	0.09	0.34	**0.06**	
Woody Wetlands	0.64	0.19	**0.36**	1.28	0.16	0.74	1.24	**0.75**	
Emergent Herbaceous	0.81	2.28	**1.73**	1.53	1.05	10.17	6.32	**3.90**	

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BROWN BEARS

Introduction

The purpose of this section is to characterize the brown bears that spend most of their lives in the Nushagak and Kvichak watersheds. Some of the general information comes from decades of research on this species in its entire cosmopolitan ranges. If variable facts are derived from study areas other than the Nushagak and Kvichak watersheds, it is so noted. However, owing to their interconnected home ranges and close genetic relationships, brown bears' habitat selection and behavior show a great degree of overlap wherever they occur (Schwartz et al., 2003).

In this section, we use the term "brown bears" to refer to all North American bears of the classification *Ursus arctos*, although bears in interior parts of North America traditionally have been referred to as grizzly bears and those on the coast, in salmon-rich areas, as brown bears. *Ursus arctos* on the Alaska Peninsula are commonly called brown bears.

Habitat

Brown bears are a wide-ranging species that, throughout the course of a year, use many different plant and animal communities. Habitat is defined here as the location or environment where an organism is most likely to be found. Habitats provide the food, water, and cover that a species needs to survive. Biologists describe individual bear's habitats as "home ranges." A home range is the normal area that an animal uses to carry out the activities of securing food, mating, and caring for young. Brown bears are generally solitary, food-maximizing individuals whose home ranges vary with the availability of their seasonal foods. When food is abundant, as is the case during salmon runs, home ranges of female bears may be smaller because of their ability to obtain sufficient energy to meet their nutritional needs. Conversely, home ranges may increase in order to take advantage of more widely dispersed food resources (McLoughlin et al., 1999).

On the Alaska Peninsula, brown bears emerge from their dens between early April and early June. Male brown bears tend to emerge before females. Females with cubs of the year are often the last to leave the den (Miller, 1990). Brown bears often spend June to mid-August in lowland and coastal areas, though probably not all bears in the Nushagak and Kvichak watersheds include coastal plains in their home ranges. A study conducted on Admiralty Island found that brown bears did not necessarily use rich coastal habitats as part of their home ranges, though the reason for these different patterns of habitat selection are not known (Schoen et al., 1986).

Brown bears typically spend July through mid-September near streams that support salmon runs (Schoen et al., 1986). The Nushagak and Kvichak watersheds contain at least 8,286 linear miles (13,335 linear kilometers) of anadromous fish habitat, not including lakes (Johnson and Blanche, 2011). As salmon begin to appear in the streams, bears move closer to them, sometimes congregating where shallow streams make preying on fish more efficient (Aumiller and Matt, 1994). Studies of bear predation on salmon in a series of streams in the Wood River system demonstrated that the probability a fish is killed by bear increases with decreasing stream size (Quinn et al., 2001).

Bears move to higher elevations in the fall, presumably to feed on berries and other food items (Collins et al., 2005). Some brown bears will continue to feed on fish until October, especially at

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shallow streams where dead and dying sockeye salmon are washing out of lakes after spawning (Fortin et al., 2007).

Dens are typically dug at higher elevations within bears' home ranges (Van Daele et al., 1990), on 20- to 50-degree slopes at between 300 and 1,600 meters in elevation. Most brown bears enter dens by early November, with a mean entrance date of October 14. In a study from the Nelchina area in south-central Alaska, brown bears spent an average of 201 days in winter dens (Miller, 1990).

Food Habits

Alaska Peninsula brown bears move within their home ranges in order to exploit seasonally available food sources (Glenn and Miller, 1980). During late summer and fall, brown bears gain weight rapidly, primarily stored as fat; peak body mass generally occurs in fall, just prior to hibernation (Hilderbrand et al., 2000). It is essential for bears to maximize weight gain prior to hibernation, since they metabolize only fat and muscle during that time and must rely on those stored energy reserves for reproduction and survival.

In the spring, after den emergence, bears commonly graze on early season herbaceous vegetation, such as cow parsnip (*Heracleum lanatum*), horsetails (*Equisetaceae*), lupine *(Lupinus spp.)*, false hellebore (*Veratrum viride*) and grasses (*Gramineae*) (ADF&G, 1985). They also search for and scavenge winter-killed carrion, as well as moose and caribou calves (Glenn and Miller, 1980). Bears with access to salt marshes commonly graze on sedges (*Carex* spp.), grasses (e.g., *Elymus* spp.), sea-coast angelica (*Angelica lucida*), and forbs (e.g., *Plantago* spp. and *Triglochin* spp.). Brown bears are also known to dig soft-shelled clams (*Mya arenaria*) and Pacific razor clams (*Siliqua patula*) on intertidal beaches (Smith and Partridge, 2004). Brown bears on the coast may also scavenge for dead marine life (Glenn and Miller, 1980).

In July through October, brown bears move to streams to take advantage of the predictable runs of salmon. The Nushagak and Kvichak Rivers provide natal homes to five species of Pacific salmon (*Oncorhynchus* spp.) and are part of the world's largest of run of salmon in Bristol Bay (Salomone et al., 2011). The abundance of salmon in the Nushagak and Kvichak watersheds makes them prime habitat for brown bears because salmon are an excellent source of lipids.

Lipids obtained through the consumption of salmon account for approximately 80% of the mass gained by bears (Hilderbrand et al., 1999b). More than other factors, the accumulation of fat determines whether brown bears will hibernate successfully, or in the case of females, produce cubs (Farley and Robbins, 1995). In addition, bigger, fatter adult females produce faster growing cubs that survive better than do cubs produced by smaller, leaner females (Ramsay and Stirling, 1988). Larger, fatter males also receive an advantage from their size. Dominance in males is necessary to win breeding opportunities and defend estrus females, and larger males tend to compete better for these opportunities than smaller males (Robbins et al., 2007).

Research conducted in Bristol Bay and Southeastern Alaska to determine factors that influenced consumption choice of salmon made by brown bears found that the availability, as well as the age and spawning status of the salmon, played a significant role in consumption choice (Gende et al., 2004). When salmon were not abundant, bears consumed more biomass of each fish, rather than just consuming body parts high in energy content. When salmon were abundant, bears ate parts of

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the fish considered to be higher in energy such as roe and the brain. In addition, bears were found to consume ripe fish before fish that had spawned-out. Some bears were even observed catching and releasing fish that had spawned-out in order to consume only ripe fish with higher energy content (Gende et al., 2004).

Brown bears are also known to feed extensively on wild fruits, including crowberry (*Empetrum nigrum)*, lowbush cranberry (*Vaccinium vitis-idaea)*, and bog blueberry (*Vaccinium uliginosum)* (Fortin et al., 2007; Rode et al., 2006a; Rode et al., 2006b). The simultaneous ingestion of salmon and berries appears to benefit bears, in terms of growth rate, compared to the ingestion of one or the other alone (Robbins et al., 2007).

Fall foraging is especially important for brown bears. In the fall, brown bears seek out available meat sources including salmon, ungulates, rodents, and mice, as well as berries, in order to store as much fat as possible. The more efficiently bears forage, the more vital lipids they can store, thereby improving their ability to live long and reproduce often (Robbins et al., 2007).

Behavior

Brown bears have generalist life history strategies, extended periods of maternal care, and omnivorous diets. A generalist species is able to thrive in a wide variety of environmental conditions and can make use of a variety of different resources such as a varied diet. Brown bears travel comparatively long distances to find the amount and variety of food they need to flourish, despite six months of hibernation.

Movement patterns that define home ranges are influenced by important food resources, breeding, reproductive status, individual dominance status, security, and human disturbance (Schwartz et al., 2003). Differences in home range size between study areas are attributed to differences in habitat quality and distribution (McLoughlin et al., 2000). The larger ranges of adult males overlap several females (Schwartz et al., 2003). Female brown bears are generally faithful to their home ranges. Sub-adult females tend to stay close to or within the home range of their mothers. However, sub-adult males tend to disperse longer distances (Glenn and Miller, 1980). Brown bears searching for alternative foods outside their usual home ranges, in particular dispersing bears, often run into more conflicts with humans, and human-caused bear mortality increases (Schwartz et al., 2003).

Different study areas illustrate the range in size of brown bear home ranges relative to habitat quality. For example, in the Nelchina River basin of south-central Alaska, adult female home ranges averaged 408 km^2, while those of adult males averaged 769 km^2 (Ballard et al., 1982). In contrast, Collins et al. (2005) estimated 356 km^2 for adult females in the southwest Kuskokwim Mountains, west of the Nushagak watershed. On the relatively productive Alaska Peninsula, Glenn and Miller (1980) found an average seasonal range of 293 km^2 for adult females and 262 km^2 for adult males. The authors were unable to gather data from a comparable sample size for adult males (n=4 males vs. n=30 females), and therefore do not support a range size comparison based on these results. They mention other parameters that seem to contradict the small male seasonal range estimated from their small sample size. For example, the cumulative 6-year movements of 13 adult males were greater than those of 49 females. In addition, they found that seasonal range movement of subadult males (744 km$^{2)}$ was three times that of subadult females (249 km^2).

During winter months brown bears hibernate in dens and rely on stored energy reserves for survival. In hibernation, bears can go up to seven months without eating, drinking, defecating, or urinating (Schwartz et al., 2003). Generally, brown bears seek out remote, isolated areas and sites that will accumulate enough snow to insulate them from cold winter temperatures, often on steep slopes. Bears may prefer steeper slopes for denning sites, due to reduced potential for disturbance (Goldstein et al., 2010).

Female brown bears enter estrus beginning around late spring and, depending upon male availability, can still breed into August. However because males are rarely limiting in a population, most breeding occurs in May and June. After the eggs are fertilized development proceeds to the blastocyst stage and then halts. Embryo implantation is delayed until hibernation begins. It is possible that a litter could have multiple sires. Female brown bears that have successfully bred and have implanted embryos have an obligate denning requirement as the newborns are completely helpless at birth and remain so for several months. Most births occur in January and February after 6 to 8 weeks of gestation. All maternal care from fetal development through the first four months of lactation occur in the den and all nutrient reserves for the developing young are drawn from maternal body stores accumulated the previous summer/fall. Litters can range from one to four cubs; however, twins are the most common (Schwartz et al., 2003).

Brown bears in the Nushagak and Kvichak watersheds interact with humans around residences, recreational sites, and in the backcountry. The behavior of bears during these interactions depends on many variables (Herrero et al., 2005). Brown bears that have received food or garbage "rewards" while near humans or their habitations can become food-conditioned. Food-conditioning is a form of operant conditioning in which bears learn to associate sources of food with humans or their infrastructure (Matt, 2010). Food-conditioned bears are more likely to encounter humans in an aggressive manner, perhaps because they assertively seek foods where humans are found. Preventing access to anthropogenic foods keeps bears from being positively rewarded for close association with people (Herrero, 2002).

Habituation describes behavior that is different from food-conditioning (Aumiller and Matt, 1994; Herrero, 2002). A habituated bear has been repeatedly exposed to a neutral situation, such as a person observing it from a close distance. Bears will conserve energy by muting their reaction. Consequently, habituation often is assumed to have occurred when bears tolerate people at close distances. Habituation is not an all-or-none response and may vary widely among individual bears. Some bears habituate to certain human artifacts such as roads and other structures (Follman and Hechtel, 1990).

Today most brown bear attacks are associated with defensive behavior, such as females protecting cubs or incidents involving protection of a food cache such as an ungulate carcass (Herrero, 2002; Herrero and Higgins, 1999; Herrero and Higgins, 2003). Whether or not a bear charges or attacks a human in a defensive manner is dependent on many factors in the immediate environment, as well as the prior experience and individual behavior of both the human and the bear (Herrero et al., 2005). Historical records strongly suggest that brown bears have not been important predators on people, although rare incidences of predation may have occurred, as they still do today (Herrero, 2002).

Interspecies Interactions

Pacific salmon (*Oncorhynchus spp.*) and brown bears meet the basic criteria of "keystone species." The loss of either species results in significant changes in the productivity, diversity and physical structure of their communities, far beyond just their "food chain" interactions. By both consuming and transporting partially consumed salmon, brown bears distribute MDNs via decaying salmon carcasses and through excretion of wastes rich in salmon nutrients (Helfield and Naiman, 2006).

Pacific salmon spend most of their lives feeding and growing at sea before returning to spawn and die in their natal streams. Approximately 99% of the carbon, nitrogen, and phosphorus in their bodies when they return to freshwater is from the marine environment (Hilderbrand et al., 1999c). These nutrients are transported inland when salmon return to their natal streams to spawn. For example, sockeye salmon (*Oncorhynchus nerka*) are estimated to import approximately 12,700 kg of phosphorus and 101,000 kg of nitrogen back to the Wood River system each year (Holtgrieve, 2009).

Nitrogen, phosphorus, and carbon are among the most important MDNs. These nutrients cycle through the ecosystem, benefitting other forms of wildlife and vegetation, promoting the production of periphyton (e.g., algae), aquatic macroinvertebrates, resident freshwater fish, and juvenile salmon (Helfield and Naiman, 2006). Insects that directly benefit from decaying salmon include stoneflies (*Plecoptera* spp.), caddis flies (*Trichoptera* spp.), mayflies (*Ephemeroptera* spp.), midges (*Diptera* spp.: Chironmids (*Chironomidae* spp.), blackflies (Diptera: *Simuliidae*), and carrion beetles (Coleoptera: *Silphidae*) (Helfield, 2001).

As salmon enter freshwater streams in late July, and throughout August, brown bears become hyperphagic (consume abnormally large quantities of food) as they store energy for winter by consuming salmon which contain protein and fat (Hilderbrand et al., 1999b). Female brown bears are each estimated to consume 1,003 kg (SD ¼ 489 kg) of salmon each year and transport approximately 37.3 kg of MDNs to terrestrial ecosystems on the Kenai Peninsula (Hilderbrand et al., 2004; Hilderbrand et al., 1999a).

In one study, brown bears delivered 83 to 84% of marine-derived nitrogen found in white spruce trees near two Kenai Peninsula creeks (Hilderbrand et al., 1999a). In addition, Helfield and Naiman (2006) found Sitka spruce growth rates to be three times greater near salmon spawning sites than in areas lacking spawning sites. Other studies also show that "bears feeding on salmon increased soil ammonium concentrations three-fold and nitrous oxide (NO_3) flux by 32 fold" (Holtgrieve, 2009).

The level of MDNs transported by brown bear shows the significance of the abundance of salmon in areas with brown bears. It also shows that loss of either population would change the nitrogen budget "and, by extension, the productivity and structure of the riparian forest" (Helfield and Naiman, 2006). The potential loss of this nitrogen source would also greatly affect other organisms throughout the food chain and ecosystem (Helfield, 2001).

Mortality, Productivity, and Survivorship

Brown bears have one of the lowest reproductive rates among mammals. This low rate is mainly due to their relatively late age of first reproduction, small average litter size, and long interval

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between litters. Their low reproductive rate makes brown bears particularly susceptible to impacts from humans (Schwartz et al., 2003). On the Alaska Peninsula, the mean age is 4.4 years at first reproduction for female brown bears (Miller and Sellers, 1992). The earliest that a brown bear female might breed is in the late spring at 4.4 years. If the female is of adequate size and nutritionally healthy, the fertilized ova develop into a blastocysts that stop developing until they implant in the uterus in late November. Following 6 to 8 weeks of gestation, tiny cubs are born within a den. The female would then emerge from her den with her surviving cubs in the late spring at 5.4 years. If cubs are raised until the typical age of weaning (2.4 years), the female's age of second breeding likely would not occur until she was 7.4 years (Schwartz et al., 2003). Therefore, during the first ten years of her life, a female grizzly bear is capable of producing only two litters.

Age at first reproduction, litter size and intervals between litters vary among populations and individuals. Litter sizes vary from one to four cubs, with twins being the most common. Females are capable of breeding in the same spring that they wean their cubs; however, they do not always wean them at 2.4 years and may keep them until the cubs are 3.4 years. Evidence shows that the average interval between litters is generally between three and six years (Schwartz et al., 2003). In a ten-year study in southwest Alaska, there was great variation in reproductive intervals (Kovach et al., 2006), although when compared to other studies in Alaska, the southwest population had one of the highest production rates of offspring, yet the lowest number of female offspring weaned per year.

Adult female brown bears that eat meat (mostly salmon) in the fall gain approximately 80% fat mass (Hilderbrand et al., 1999b). Deposited fat is more important than lean body mass in producing cubs during winter dormancy (Farley and Robbins, 1995). While late summer and fall salmon are a critical resource on their own, it is the likely the availability of both fall berries and salmon, together, enable brown bears to accumulate body reserves important for reproduction and hibernation (Hilderbrand et al., 1998; Robbins et al., 2007). While it seems logical that productivity (independent of mortality) would be higher in populations with access to salmon in the fall, Kovach et al. (2006) found that, in southwest Alaska, females had only slightly higher productivity than the figures reported for Yellowstone National Park and the Selkirk Mountains, where salmon are not present (Kovach et al., 2006).

The age and sex structure of brown bear populations is dynamic. Many variables, such as habitat conditions, time of year of observations, and hunting make generalizations difficult. However, in one study of a hunted population on Kodiak Island, the population structure of brown bears was 26% cubs, 22% yearlings, 27% sub-adults, and 25% adults (Troyer and Hensel, 1964). The number of cubs born varies from year to year, and the proportion of cubs in any brown bear population is a function of both reproductive rate and early mortality. Cub survival rates, based on observation of den emergence from the first year to the second year, were estimated for two areas on the Alaska Peninsula. At Black Lake, cub survival was an estimated 57%, while cub survival in Katmai National Park was an estimated 34% (Miller et al., 2003).

Survival of adult males varies among populations, but is generally lower in hunted populations. In 1985, in the middle Susitna River basin study area in south-central Alaska, there was an estimated 82% annual survival for adult males (Miller et al., 2003). Ten years later, in 1995, Miller et al. estimated only 71% annual survival for adult males, due to increased hunting pressure. Female survival rates are generally higher than males. In the middle Susitna study, Miller et al. (2003)

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estimated 90% annual survival for adult females in both 1985 and 1995. In their study of female survivorship in a hunted population in the southwest Kuskokwim Mountains, midway between Dillingham and Bethel, Alaska, Kovach et al. (2006) found mean annual survival estimates of 90.1 to 97.2% for radio collared females aged five years or older.

Due to the difficulty of observing entire life histories of brown bears, the causes of natural mortality are not well known. While it is known that adult males kill juveniles and that adults kill other adults, there are insufficient data to fully assess the effects of predation on younger bears by adult bears (Schwartz et al., 2003). Brown bears are exposed to more dangers during some life stages than others. Survival rate estimates for cubs during their first year of life shows particular vulnerability. In the middle Susitna study, survival for cubs of the year was estimated at 67% (Miller et al., 2003). Kovach et al. (2006) reported survival rates of 48.2 to 61.7% for cubs of the year.

In the latter study, researchers estimated survival rates of 73.3 to 83.8% for one- and two-year-old offspring, combined. Dispersing sub-adults may be forced to choose marginal home ranges or areas near human habitation that are dangerous to their survival (Servheen, 1996). Brown bears can be afflicted with parasites and diseases that may contribute to their demise from other causes such as starvation. However, there are no known instances of parasites or diseases causing major die-offs within populations (Schwartz et al., 2003).

In many brown bear populations, human-caused mortality is higher than natural mortality. The rate of human-caused mortality varies greatly in Alaska, where contact between bears and humans is a function of human population density, activities of both species, and hunting regulations. Servheen (1996) lists the following categories of human-caused mortality, in order of frequency: direct human/bear confrontations (hikers, backpackers, photographers, hunters, etc.); attraction of grizzly bears to improperly stored food and garbage associated with human habitations and other sources: careless livestock husbandry, including the failure to properly dispose of dead livestock; inadequate protection of livestock; loss of bear habitat; and hunting, both lawful and illegal.

Population

Brown bear population abundance is usually measured in terms of density, since it is widely considered to be the most biologically meaningful measure of abundance. Two methods for estimating bear population density, capture-mark-recapture, and aerial line-transect survey, have been used recently in Alaska. Both estimates survey in the early spring, prior to leaf growth on deciduous shrubs and trees.

Alaskan brown bear populations vary significantly in density depending on the availability and distribution of food (Miller et al., 1997; Schwartz et al., 2003). Brown bear populations achieve maximum densities in areas where the populations have access to multiple runs of Pacific salmon (Hilderbrand et al., 1999c; Miller et al., 1997). Based on a modified capture-mark-recapture method for estimation, the Pacific Coast of the Alaska Peninsula has the highest documented brown bear density in North America, at 551 bears (representing all ages) per 1,000 km^2 (Miller et al., 1997). The North Slope of Alaska has the lowest estimated density at 3.9 bears of all ages/1,000 km^2 (Reynolds, 1976).

While population density estimates for the entire Nushagak and Kvichak watersheds are not currently available, recent aerial line-transect studies in portions of the watersheds and in nearby watersheds can give some idea about brown bear densities. Using the double observer aerial line-transect method, brown bear density in the Lake Clark National Park and Preserve portion of the Kvichak watershed was estimated at 39 bears/1000 km^2 (1999 E. Becker personal communication). Recent aerial line transects in the remainder of the inland Kvichak watershed reveal an estimated 47.7 bears of all ages/1000 km^2 (Becker, 2010). In the nearby northern Bristol Bay area (Togiak NWR and Bureau of Land Management Goodnews Block), brown bear population density was 40.4 bears/1,000 km^2 (Walsh et al., 2010). The later study included both coastal and inland habitats.

As expected, surveys that include coastal habitat have higher population density estimates during spring. Researchers using the same line-transect survey method as in the above studies, estimated brown bear density at 124 bears/1,000 km² in Katmai National Park, an area that included both coastal and inland brown bear habitat. Along the coast of Lake Clark National Park and Preserve (NPP), brown bear density was estimated at 150 bears/1,000 km².

When inferring the distribution of brown bears from density estimates, it should be noted that brown bears move long distances across the landscape. Bears that are counted in coastal areas in the spring may move inland and upstream in the summer and fall to take advantage of pre- and post-spawning salmon. It is common to see brown bears in interior Lake Clark NPP feeding on post-spawning salmon in September and October, and less commonly, in December (Mangipane, personal communication). Fortin et al. (2007) recorded brown bears feeding on salmon into October on the Kenai Peninsula.

Human Use/Interaction/Management

Major human "uses" of brown bears in the Nushagak and Kvichak watersheds include sport hunting, subsistence hunting, and bear viewing. Besides these uses, there are many other interactions between brown bears and humans, including both residents and non-residents visiting the area for purposes other than seeking encounters with brown bears.

Sport Hunting for Brown Bears

Game Management Unit 9- The Alaska Board of Game has placed a high priority on maintaining a quality hunting experience for the large brown bears of the Alaska Peninsula in Game Management Unit (GMU) 9, which includes the Kvichak watershed (Figure 3). Due to relatively easy aircraft access and the high quality of bear trophies in the unit, an active guiding industry for the area developed during the 1960s. Non-resident sport hunters are required to use a guide for brown bear hunting throughout Alaska, and to have their harvest inspected and sealed by ADF&G. The ADF&G management program strives to maintain stable guide and client numbers over time. As of 2007, approximately 75% of the GMU 9 brown bear harvest came from guided hunts (ADF&G, 2009).
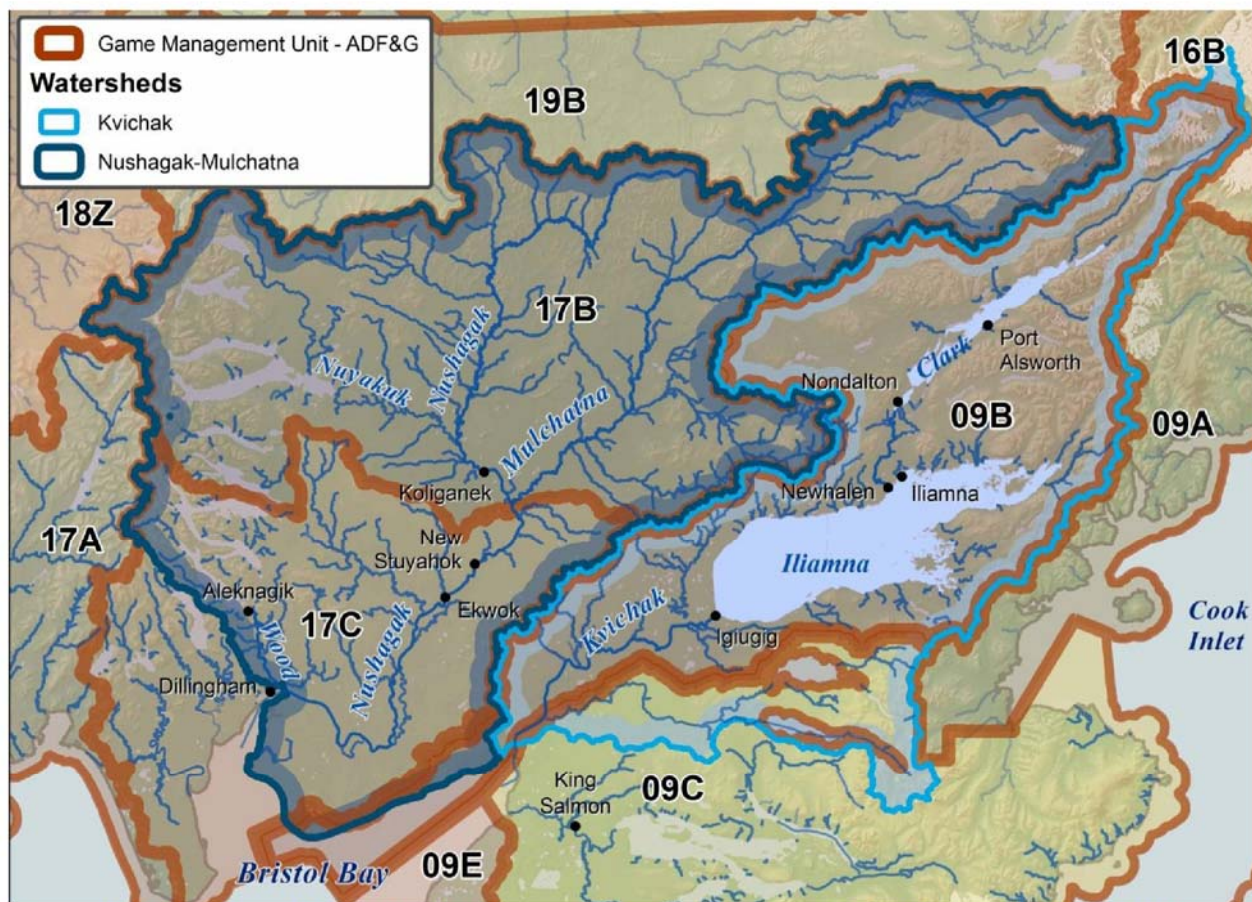
Figure 3. Nushagak and Kvichak River watersheds and associated Alaska Department of Fish and Game, game management units.

The current brown bear management objective for GMU 9 is to maintain a high bear density with a sex and age structure that will sustain a harvest composed of 60% males, with 50 males aged eight years or older taken during the combined fall and spring seasons. In GMU 9, in the 2007 Regulatory Year (July 1, 2006 through June 30, 2007), results reported to ADF&G revealed a harvest of 621 bears (72% male and 28% female).

Game Management Unit 17- In GMU 17, which includes the most of the Nushagak River watershed, brown bears are neither as abundant nor, usually, as large as those found on the Alaska Peninsula. GMU 17 has not received much hunting pressure in the past. However, interest in hunting brown bears in many parts of Alaska is increasing, and bear hunting in GMU 17 has increased substantially since the mid-1990s. As of 2007, the brown bear population objective for GMU 17 was to maintain a brown bear population that will sustain an annual harvest of 50 bears composed of at least 50% males (ADF&G, 2009).

Subsistence Hunting for Brown Bears-
On non-federal lands in GMUs 9b and 17, subsistence brown bear hunters must obtain a subsistence registration permit for bears to be taken for food. In addition to requiring a registration permit, the subsistence brown bear hunting regulations establish a hunting season of September 1 to May 31, limit take to one bear/regulatory year, and prohibit take of cubs and sows with cubs (ADF&G, 2011a). Salvage of the hide and skull is optional and the hide and skull need not be sealed, unless they are removed from the Western Alaska Brown Bear Management Area, in

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which case they must be sealed by an ADF&G representative and their trophy value destroyed. All edible meat must be salvaged for human consumption. On federal lands within GMUs 9 and 17, residents must consult the Federal Subsistence Management Program Regulations, available at http://alaska.fws.gov/asm/law.cfml?law=2&wildyr=2010. There are some differences between federal and State subsistence hunting regulations. For example, on federal lands in GMU 9B, there is a federal registration permit harvest quota of four females or ten bears and the season closes as soon as the first quota is reached.

Bear Viewing-
Within the Kvichak watershed there are specific destinations for recreational visitors to view brown bears. Lodges on Lake Clark, Kukakluk Lake, Nonvianuk Lake, and Battle Lake offer brown bear viewing in addition to fishing expeditions. Several guides and air taxis take brown bear viewers to Funnel Creek and Moraine Creek on day trips.

The 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation reported that 491,000 Alaskan residents and non-residents participated in wildlife watching as a primary activity (USFWS and US Department of Commerce Census Bureau, 2006). Bear viewing is now the leading recreational activity in Lake Clark NPP. The incidental "use" of bears has spatiotemporal impacts to the bear use (Rode et al., 2007; Tollefson et al., 2005).

Other Human-Bear Interactions

Local Residents and Bear-Human Conflicts-
In both GMU 9 and 17, the number of bears killed annually includes both legally harvested bears and reported non-hunting mortalities. Villages with open landfills attract bears during the spring, summer, and fall. Residential garbage, dog food, and fish drying racks also bring bears close to humans. Incidences of local residents killing bears in defense of life and property near villages and fishing sites are not uncommon. Although reporting rates seem to have improved in recent years, most non-hunting mortalities of bears are reported either indirectly or not at all; as such, any conclusions based solely on harvest data or reported non-hunting mortalities should be viewed with caution (ADF&G, 2009).

During the 2007 regulatory year, in GMU 9, ADF&G received 17 reports of bears killed by people in defense of life and property; however, wildlife managers estimated that the number of unreported brown bear killings in the unit might be over 50 when considering unreported data. During the same period in GMU 17, ADF&G received 5 reports of defense of life and property mortalities; however wildlife managers assumed there were more unreported brown bear killings (ADF&G, 2009).

Other Recreational Users and Bear-Human Conflicts-
In Lake Clark NPP, park managers analyzed 171 bear-human incidents over 24 years. They found that, in 46% of the incidents, brown bears received food as a result of the encounter. Bears were killed in 23% of the incidents (Wilder et al., 2007). Managers were concerned about the large number of food-conditioning incidents, given that food-conditioned bears are responsible for the majority of human injuries from bears in national parks (Herrero, 2002; Wilder et al., 2007). Food-conditioned bears have been found to be 3 to 4 times more likely to be killed by humans than non-food conditioned bears (Mattson et al., 1992). Wilder et. al. (2007) also noted that casual bear photographers at private recreational cabins at Telequana Lake, may have contributed to the high number of bear-human incidents, saying "that individuals repeatedly fed bears in this area to facilitate photography."

MOOSE

Introduction

Moose, the largest member of the deer family (*Cervidae*), have a circumpolar distribution in the northern hemisphere (ADF&G, 2011d; Telfer and Kelsall, 1984), occupying a broad band of boreal forest dominated by spruce, fir, or pine trees. Fire is a major force that shapes these vegetative communities (Odum, 1983; Telfer and Kelsall, 1984). Moose occur in northern forests of North America, Europe, Russia, and China (Karns, 2007). The association between moose and the northern boreal forest is unique, as there are no counterparts in the southern hemisphere (Shelford, 1963). There are four recognized subspecies of moose in North America (Hundertmark et al., 2003; Peterson, 1952; Peterson, 1955); the one found in the study area (Nushagak and Kvichak watersheds) is the Alaska-Yukon subspecies (*Alces alces gigas*) (Miller, 1899). This subspecies is often referred to as the "tundra moose," since it is often found in and near tundra areas (Bubenik, 2007). However, it also inhabits the boreal forest, low elevation riparian and delta habitats, and mixed deciduous forest areas. The Alaska-Yukon subspecies is generally larger than the other subspecies in body size and antler development. In Alaska, moose are found in suitable habitats throughout the mainland portion of the State, except on the northernmost coastal plain (LeResche et al., 1974), ranging from the Stikine River in southeast Alaska to the Colville River on the Arctic Slope (ADF&G, 2011d). Moose are ruminants, with a four-chambered stomach, and are classified as browsers based on their foraging strategy (Hoffman, 1973). These herbivores consume mainly tree and shrub leaves and woody twigs during winter (Renecker and Schwartz, 2007). Due to their large body size and the volume of vegetation consumed, moose play an important role in plant productivity and nutrient cycling in ecosystems where they occur (Molvar et al., 1993).

Here we characterize moose that inhabit the Nushagak and Kvichak watersheds, but we provide substantial information accumulated from decades of research on this species from across North America. Since moose are a generalist species, much of this information is relevant to moose in the Nushagak and Kvichak areas. We borrow heavily from the work of a distinguished group of moose biologists, which provides a near complete summary of moose biology and management (Franzmann and Schwartz, 1998; Franzmann and Schwartz, 2007) and have attempted to cite them when appropriate. We also relied on a separate, condensed version of these data with more recent updates (Bowyer et al., 2003).

Habitat

Both stable and transitory habitats are important in the evolution of moose (Geist, 1971). Permanent habitats are those that persist through time without alteration in character or condition, such as riparian willow/poplar communities and high-elevation shrub/scrub communities that do not succeed to different kinds of vegetation (Peek, 2007). Telfer (1984) characterized the full range of moose habitats to consist of boreal forest, mixed forest, large delta floodplains, tundra subalpine shrubs, and stream valley/riparian zones. According to Peek (2007), boreal forest habitats are considered fire-controlled and likely represent the primary environments in which moose evolved (Kelsall and Telfer, 1974; Peterson, 1955). As noted by Peek (2007), delta floodplains are expected to have the highest density of moose, followed by shrub/shrub habitats, boreal forests, mixed forests, and stream valley/riparian zones. A study in the Copper River Delta supported the finding that large deltas and floodplains are the most productive of these five major habitat types for moose (MacCracken et al., 1997b). Boreal forest habitats are the least stable

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through time, whereas stream valley/riparian zones are the most stable. In Alaska and the Northwest Territories, the climax tundra and subalpine shrub communities at higher latitudes and elevations are more stable in time and space than the alluvial and riverine habitats (Viereck and Dyrness, 1980).

Transitory habitats of moose include boreal forests where fire creates successional shrub communities that provide extensive forage. Geist (1971) hypothesized that islands of permanent habitat found along water courses and deltas, and in the high elevation dwarf shrub communities, serve as refugia where moose populations persist and from which they disperse into transient habitats created by fire. The common occurrence of fire in boreal forests is considered sufficient to promote adaptations favoring dispersal of yearling moose to newly created habitats (Peek, 2007). The dominant land cover types in the study area consist of high elevation dwarf shrub, shrub/scrub and tundra habitats, with lower elevation boreal forests (deciduous, evergreen and mixed) and riparian habitats (woody wetlands) along water courses (Table 1). All of these cover classes represent high-quality moose habitat.

Habitat selection by moose is influenced by availability of food, predator avoidance, and snow depth (Dussault et al., 2005). Peek (2007) advanced the view that moose select habitat primarily for the most abundant and highest quality forage. Since these resources are unequally distributed in space and time, moose habitat may be considered as a series of patches of different kinds and sizes, with the value of each patch varying through the year. However, the total year-round value of a diverse habitat should be emphasized even if each part is only critical at one season or another. Peak (2007) further stated that the caveat to this general proposition was that sufficient size of both overall habitat, and possibly each patch of any given habitat, must be accessible to make an area most suitable for occupation by moose. As a corollary, if a certain critically important community, such as shrub/scrub vegetation type, is unavailable in sufficient quantity, then the ability of an overall habitat to support moose may be reduced even if it contains a highly diverse set of other plant communities.

The typical annual pattern of moose habitat selection includes open upland and aquatic areas that provide the best forage in early summer, followed by more closed canopy areas that provide the best forage as summer progresses and plant quality changes. In autumn, after the rut and into winter, moose intensify use of open areas with the highest biomass of dormant shrubs, where the remaining major source of palatable forage occurs. Closed canopy areas are used in late winter when forage is naturally at its lowest value and quantity for the year. The nature of the cover used at this time will provide the best protection available from wind and cold, and may range from tall shrub communities to tall closed canopy conifer stands (Peek, 2007). Metabolic activity in moose generally corresponds to this pattern, being highest in summer and lowest in winter (Regelin et al., 1985). Alaskan moose generally do not use areas > 1,220 m in elevation (Ballard et al., 1991). Also, in Alaska, because forage quantity and quality (nutritional value) in summer and winter can differ by orders of magnitude, winter habitat availability is often the ultimate limit on moose abundance (Stephenson et al., 2006). Spatial heterogeneity of habitat on a relatively small scale ($\leq$ 34 km^2) enhances habitat quality for moose (Maier et al., 2005), probably because it enables moose to respond to rapidly changing conditions such as climate (Stephenson et al., 2006).

Moose benefit from early successional stages of vegetation, which provide the woody browse biomass that moose require (Schwartz, 1992). A disturbance regime that provides persistent shrub communities, distributed in a diverse mosaic on the landscape, is essential to high moose density

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(Stephenson et al., 2006). In Alaska, this disturbance can be provided by fire (LeResche et al., 1974; Maier et al., 2005), glacial outwash, and earthquakes (Stephenson et al., 2006). On the Kenai Peninsula, forest succession following fire provided the most abundant forage for moose 20 years post-burn (Bangs et al., 1985; Schwartz and Franzmann, 1989; Spencer and Chatelaine, 1953; Weixelman et al., 1998). Schwartz and Franzmann (1989) reported that, after the 1969 fire, moose abundance peaked about 15 years after the burn, when browse plants reached maximum productivity. The increase was attributed to high production and low mortality, with some initial shifting of home ranges from adjacent high-density populations. Where fire was absent for 25 years, moose densities on the Kenai Peninsula were sufficiently high to cause the forage base to shift from a multispecies complex to a much less diverse community dominated primarily by white birch (Oldemeyer et al., 1977). In the boreal forest, the optimum successional stages for moose are 11-30 years after burning (Kelsall et al., 1977).

In Game Management Unit (GMU) 17 in northern Bristol Bay, moose habitat is enhanced primarily by the scouring of gravel bars and low-lying riparian areas by ice and water during the spring thaw (Woolington, 2008). Willows and other plants quickly regenerate after bank scouring and subsequent deposit of river silt (Woolington, 2004). This disturbance mechanism is particularly important for the Nushagak and Mulchatna Rivers and for the lower reaches of the major tributaries to those rivers (Woolington, 2008). Major river systems with large riparian zones, like the Nushagak and Mulchatna Rivers, represent alluvial habitats that support an abundant moose population, because they feature an abundance of nutritious food, primarily in the form of regenerating willow stands. Deciduous shrubs proliferate in these areas because of the annual influx of nutrients from waterways, sufficient soil moisture, and changing river channels. Lightning-caused wildfires also occur occasionally in GMU 17 (Woolington, 2008), and provide disturbance that enhances moose habitat. Moose habitat has not been formally assessed for GMUs 17B and 17C. Much of GMU 17 is wet or alpine tundra, and moose are located mostly along the riparian areas (Woolington, 2008).

In interior Alaska, habitat characteristics and female moose densities were evaluated using a spatial linear model (Maier et al., 2005). The densest moose populations occurred closer to towns, at moderate elevations, in areas with greatest amounts of riparian habitat, and in areas where fire occurred between 11 and 30 years prior. Moose avoided non-vegetated areas. Female moose preferred areas with patch richness, indicating their need for a diverse habitat with both food and availability of concealment. It was postulated (Maier et al., 2005) that moose might have preferred to be near towns either because human disturbance of vegetation provides high-quality foods for moose, or because predators such as wolves and grizzly bears tend to avoid human-inhabited areas.

On the Copper River Delta, open tall alder-willow and low sweetgale-willow habitats were used most by moose, and use of closed tall alder-willow habitat was intermediate (MacCracken et al., 1997b). Aquatic and woodland spruce habitats were used the least by Copper River Delta moose. Aquatic plants were used seasonally by Copper River Delta moose during the period from April through August, and were used primarily for foraging by both sexes (MacCracken et al., 1993).

In northwest Alaska during March and April, moose occurred at stands of felt-leaf willow (*Salix alaxensis*) 85.0 % of the time, followed by other willow (*Salix*) (6.4 %), riparian areas (3.9 %), gravel bars (2.5 %), and upland areas (1.3 % of the time) (Gillingham and Klein, 1992).

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**Winter Habitat-** The influence of snow on moose habitat use patterns has received considerable attention. In severe winters, snow depth can be a limiting factor for moose populations. Deep snows can reduce browse availability by burying it, and travel through deep snow increases energy expenditure (Ballard et al., 1991). Snow characteristics of ecological significance include temperature, density, hardness and depth (Peek, 1986). Since the temperature of snow fluctuates less than ambient temperatures and never gets as low as the air temperature, snow provides insulation for moose against temperature extremes (Peek, 2007). Density and hardness influence the ability of an animal to travel across or through the snowpack. Under some conditions, snow density can be sufficient to support the mass of a wolf, but not a moose. Under these circumstances wolf predation on moose tends to be high (Ballard and Van Ballenberghe, 2007). It has been shown for other cervids (mule deer and elk) that energy expenditure while moving through snow increases exponentially with increasing snowpack maturation through the winter. Hardness and density affect sinking depth, and snow level at front knee height has been suggested as a threshold parameter (Parker et al., 1984). Applying the same principals and relationship to moose, a snow depth beyond 50-60 cm would result in a relatively large increase in energy expenditure for movement (MacCracken et al., 1997a). Snow depths ranging from 70–100 cm have been shown to limit the travel of moose (Des Meules, 1964; Kelsall, 1969; Kelsall and Prescott, 1971). When snow depths approach 97 cm, moose have been confined to areas where forest canopies are dense (Kelsall and Prescott, 1971).

The distribution of snow within the forest influences moose habitat use patterns. Snow depth is nearly always greater in open areas until late winter, when snow exposed directly to the sun melts more rapidly than snow protected by tree canopies. Snow falling on tree branches of fine-needled conifers, such as spruce, tends to be retained in the canopy and produces a lower snow depth immediately beneath the tree canopy in areas called a tree well (Pruitt, 1959). When this snow sheds from the tree branches to the ground, it tends to produce a hard dense surface, which provides more support for moose traveling beneath the canopy (Peek, 2007). In some geographic locations with deep winter snow, mature coniferous forests can provide zones of shallow snow accumulation that benefit moose survival (Balsom et al., 1996). In deep snow habitats where conifers are absent, such as in shrub/scrub tundra or riparian communities, moose still use the best microsites offered by combinations of shrub canopies and topographical situations that reduce snow depths. However, the principal adaptation simply is to reduce energy expenditure (Peek, 2007).

Severe winters have been associated with high moose calf mortality from starvation (Ballard et al., 1991). In Quebec, females with calves had a greater preference for habitats providing protection from predators, while solitary adult females preferred habitats with moderate food abundance, moderate protection from predators, and substantial shelter against deep snow (Dussault et al., 2005). In Denali National Park and Preserve (DNPP) during the severe winter of 1986, large males were the only moose able to remain in the Jenny Creek unit, which had a higher forage biomass but deeper snow than other units (Miquelle et al., 1992). Moose are very tolerant of cold temperatures, but are susceptible to heat stress. The upper critical temperature range for moose during winter is -5 to 0°C; during the summer upper thermal limits are 14 to 20°C (Renecker and Hudson, 1986).

Food Habits

The moose diet is comprised mainly of leaves, twigs and bark of woody plants (Schwartz, 1992; Van Ballenberghe et al., 1989). Renecker and Schwartz (2007) reviewed the diet items consumed by moose. They list more than 221 plant genera/species, with willow (Salix), birch (Betula), and alder (Alnus) predominating across North America. Daily patterns of moose use of time and space explain how the animal satisfies hunger, remains fit, avoids thermal stress, maintains security from predators, and reproduces. Since many of an individual moose's life cycle needs interact daily, tradeoffs often occur, because most requirements are more critical at certain times than at others. The day-to-day needs of moose for food and thermoregulation are most often preempted in favor of other activities that accommodate fitness and mating. However, the survival instinct is satisfied most on a daily basis by optimizing food consumption at minimal risk and effort. In this regard, a basic constraint for most moose is an abundant food supply of low quality (Renecker and Schwartz, 2007).

Digestive strategies of wildlife species vary significantly. Moose are ruminants, with a four-chambered stomach. In ruminants, browse, forbs, and grass are held in the large-chambered rumen of the stomach until adequate nutrients are extracted from the fibrous materials and the plant particles are small enough to pass through to the omasum and true stomach. On the basis of feeding habits, specialization and design of the digestive anatomy, ruminants are classified into three main groups (Hoffman, 1973): browsers that eat mainly shrubs and trees, grazers that eat mainly grass, and mixed or intermediate feeders that eat a mixture of grass, forbs, and browse. The moose is a browser and has been classified as a seasonally adaptive concentrate selector (Hofmann, 1989). Concentrate selectors have a relatively small ruminoreticular chamber and must search for high-quality foods that will pass rapidly through the digestive system. Moose consume plant species and parts (twigs and foliage) high in cell-soluble sugars that ferment rapidly in the rumen. They generally avoid plants that are fibrous and require extensive breakdown in size before passage from the rumen. Moose have a relatively narrow muzzle, prehensile lips and tongue that allow them to select high-quality plant parts (Renecker and Schwartz, 2007). Moose ferment (digest) mostly the soluble components of their food, and propel digesta rapidly through their digestive system (Schwartz, 1992). Their digestive efficiency is regulated by forage selection, rumination, gut morphology, and mechanisms controlling the rate of passage of food (Schwartz, 1992). Moose can ingest and process high-quality foods more rapidly, (e.g., aquatic plants eaten in summer), because both passage and digestion rates are enhanced (McArt et al., 2009).

In the range of moose, plant species respond to seasonality by growing during the short summers and entering a state of dormancy during long the winters. As plants change seasonally so does their nutrient quality. Plants begin their growth phase in early spring, long before actual green-up occurs. In general, spring and summer foods are 1.5 to 3 times more nutritious than winter foods, depending on which constituent is examined (Schwartz and Renecker, 2007). Summer diets contain excess digestible energy and protein, whereas winter diets generally are insufficient to meet maintenance requirements (Renecker and Hudson, 1989; Schwartz et al., 1988; Schwartz et al., 1987). As a result, feeding habits of moose vary by season, via a complex interaction of internal physiological regulators and the external environment. There is an annual cycle of food selection and intake, fat metabolism, metabolic rate, and body mass dynamics that is not driven simply by food quality and availability (Schwartz, 1992). The gastrocentric hypothesis predicts that large male moose will eat large amounts of low quality, fibrous foods, while smaller-bodied

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females will consume smaller amounts of higher-quality forage to meet the demands of reproduction and lactation (Oehlers et al., 2011). Both sexes reduce food consumption and metabolic rates in the winter, and operate at a net energy deficit by utilizing fat reserves (Miquelle et al., 1992; Schwartz, 1992).

Protein and energy are considered the major limiting nutrients within the environment (Schwartz, 1992). Summer protein intake is critical for lactating female moose (McArt et al., 2009). Tannins have a negative influence on forage quality, because they quantitatively reduce protein availability (Robbins et al., 1987). In two areas of Alaska, browse quality differences were consistent with observed differences in moose reproductive success (McArt et al., 2009). In recent years, the productivity of DNPP moose has been significantly higher than that of moose in the Nelchina Basin. A study of browse quality in the two areas found that, on average, nitrogen levels were 9% lower and tannin levels 15% higher in Nelchina than in DNPP, resulting in a digestible protein differential of 23%. The researchers concluded that the Nelchina moose population was nitrogen-limited. In both systems, browse quality declined significantly as summer progressed, with nitrogen levels decreasing and tannin levels increasing in all species of browse studied. In comparison with early-summer forage, digestible protein had decreased by an average of 35% by mid-summer and 70% by late summer (McArt et al., 2009).

High-quality summer forage, particularly near wetlands, allows nursing cows to regain body condition and calves to grow so they can better escape predators and survive their first winter (ADF&G, 2011d). During the spring-summer period, moose feed in aquatic habitats. In the Copper River Delta, aquatic habitats produced about four times more forage than terrestrial habitats, and the forage was more digestible (MacCracken et al., 1993). While some researchers have linked the summer consumption of aquatic plants by moose to a craving for sodium (Jordan, 1987), the Copper River Delta data did not support that hypothesis. Those data suggested that moose selecting aquatic forage were switching from an energy-maximizing to a time-minimizing strategy (MacCracken et al., 1993). This is because aquatic plants are high in water content and although a moose can fill it's rumen quickly, the relative quantity of dry matter consumed is less than when eating the same amount of terrestrial vegetation, such as leaves. Although a relatively small part of the wild moose diet, another forage type selected seasonally by moose is bark. Bark stripping occurs mostly in winter, when there are a lesser number of twigs available due to snow depth (MacCracken et al., 1997b). In DNPP, female moose also stripped bark in aspen-spruce forests in May and June, coincident with birth and lactation (Miquelle and Van Ballenberghe, 1989). Studies have also identified certain plant species that moose avoid because of low palatability due to chemical defenses in plants, such as black cottonwood (*Populus balsamifera trichocarpa*) on the Kenai Peninsula (Weixelman et al., 1998) and white spruce (*Picea glauca*) both on the Kenai and in other parts of Alaska (Weixelman et al., 1998).

Moose in the Copper River Delta consume three different diets that vary among the seasons of winter, spring/early summer, and late summer/fall (MacCracken et al., 1997b). Willow dominated all three diets; the differences were related to the amounts of sweetgale (*Myrica gale*), marsh five-finger (*Potentilla palustris*) and graminoids in the diet. Winter diets included sweetgale and alder (*Alnus* spp.), which are both nitrogen-fixers, leading to relatively higher protein content. Spring/early summer diets were most diverse, due to the increased use of emergent aquatic plants such as marsh five-finger. Late summer/fall diets were least diverse, consisting almost entirely of willow leaves and twigs (MacCracken et al., 1997b).

Moose diets in DNPP were also found to vary by season. In the summer, seven species of willow comprised a total of 81.5% of the diet (Van Ballenberghe et al., 1989). In that study, diamond-leaf willow (*Salix planifolia*) was eaten more than any other plant species in summer (45.7% of diet). In contrast, willow comprised over 94% of the total diet of DNPP moose in winter (Risenhoover, 1989).

Moose can influence the composition and productivity of the terrestrial plant community through browsing (Bedard et al., 1978). In DNPP, moose initiated positive feedback loops on their environment through browsing (Molvar et al., 1993). Willows exhibited a growth response to moose herbivory; specifically, leaf area was significantly greater at the site with high moose density than at the site with low moose density. Annual biomass productivity per growing point on willow stems increased with increasing browsing intensity on the plant as a whole, via release from apical dominance. Moose also increase rates of nutrient cycling, as their urine and feces transfer nutrients to soil. The organic content of soil can also be enhanced by moose, in turn benefitting microbiota such as decomposers (Molvar et al., 1993). In a study in interior Alaska, twigs re-growing from two-year old willow stems that had been browsed by moose had larger diameters than those that had not been browsed in the previous year (Bowyer and Neville, 2003). Browsing on felt-leaf willow did not have an effect on nitrogen content, digestibility, or tannin content, which indicated that the willow did not exhibit a tannin-mediated inducible defense system in response to herbivory (Bowyer and Neville, 2003).

Marine derived nutrients (MDNs) carried upstream by spawning salmon have implications for nutrient flow into riparian habitats, and are thought to enhance growth and productivity therein (Quinn et al., 2009). While it is plausible that MDNs might contribute to increased plant productivity and thus benefit moose, evidence of this direct impact was not located in the scientific literature.

Moose density is often associated with food abundance (Eastman and Ritcey, 1987; Joyal, 1987; Oldemeyer and Regelin, 1987; Schwartz and Franzmann, 1989; Thompson and Euler, 1987). As reviewed by Renecker and Schwartz (2007), forage biomass varies with successional age of forests. In Newfoundland, available woody biomass increased from about 200 kg/ha in two-year-old clear cuts to more than 2,000 kg/ha by eight years, at which time it peaked and subsequently declined gradually (Parker and Morton, 1978). On the Kenai Peninsula, important browse species peaked about 15 years after fire (Spencer and Hakala, 1964). The biomass of important browse species in successional stands of forest has been estimated on the Kenai NWR; browse production measured at 3, 10, 30, and 90 years post-burn was 37, 1,399, 397, and 4 kg/ha, respectively (Oldemeyer and Regelin, 1987).

Behavior

Movements and Home Ranges- The ways in which moose use their environment both spatially and temporally are of great interest to resource managers (Hundertmark, 2007). The dynamics of animal movements and distribution in space and time are integral to behavioral, ecological, genetic, and population processes. Thus, the attributes of the space occupied by individual animals, both annually and seasonally (home ranges), patterns of movement within home ranges, establishment of new home ranges by young moose and colonization of new habitats *(*dispersal) and movements between seasonal ranges (migration) must be considered in comprehensive management programs.

The size of a moose home range varies with the sex and age of the animal, season, habitat quality, and weather. Two studies from Alaska generated the largest estimates of home range size, although one of these (Grauvogel, 1984) included migratory locations in the estimate of seasonal ranges, which can increase home range size significantly (Hundertmark, 2007). Moose in south-central (Ballard et al., 1991) and northwest Alaska had mean seasonal ranges > 92 km^2. With the exception of home ranges of non-migratory adults in the later study, total home range sizes exceeded 259 km^2. In contrast, estimates of annual ranges for moose in northwest Minnesota were ≤ 3.6 km^2 (Phillips et al., 1973).

Seasonal ranges, when they exist, represent partitioning of the environment based on behavioral and energetic constraints. Migratory moose (those that use separate winter and summer ranges) use distinct seasonal ranges because they attempt to optimize their nutrient intake on summer range, but winter conditions on these ranges may preclude occupation during some or all winters. Moose that remain on the same range during winter and summer are termed non-migratory, and do so because the environmental conditions permit their residence. A third seasonal range associated with mating, occurs in autumn, but many investigators define this as part of the summer range (Hundertmark, 2007). Breeding areas for tundra moose are typically in open habitats where visibility is good. This is likely for behavioral purposes so bulls and cows can see each other as they display. It may also afford some predator protection.

In several moose populations studied in Alaska, some individuals were non-migratory residents while other individuals migrated seasonally. In the Copper River Delta, 8 of 15 collared females were migratory, while two of five collared males were migratory (MacCracken et al., 1997b). Moose in that area exhibited greater fidelity to their summer range than their winter range (MacCracken et al., 1997a); winter severity influenced winter migratory behavior from year to year in the Copper River Delta (Stephenson et al., 2006). Moose populations in south-central Alaska (GMU 13, comprising the Nelchina and upper Susitna basins) also included both migratory and non-migratory individuals (Ballard et al., 1991). Those moose exhibited three seasonal periods of movement – autumn migration to wintering areas, spring migrations to calving areas or summer feeding grounds, and early fall migrations to rutting areas (Ballard et al., 1991). In the Togiak River drainage of the northern Bristol Bay area (GMU 17A, the), some collared moose were resident whereas others migrated seasonally (Woolington, 2008). During a population estimation survey in February 1995, 29 moose were documented moving westward from the upper Sunshine Valley in GMU 17C (the lower Nushagak watershed) into GMU 17A (Woolington, 2008).

Cows with new-born calves restrict their movements for the first few weeks, after which they gradually expanded their home range to approximate home range size of other adults (LeResche, 1974). In one study, cow-calf pairs had smaller summer home ranges than did other moose, and calf movements increased exponentially with age during the first six weeks of life (Ballard et al., 1980).

When differences in annual home range sizes are attributed to sex, males always are found to occupy larger areas. In south-central Alaska males had significantly larger home ranges than did females (Ballard et al., 1991). In northwestern Alberta researchers noted no difference between the sexes, but did note the tendency of bulls to occupy larger winter and spring home ranges (Lynch and Morgantini, 1984).

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The timing of seasonal migration has been observed to vary significantly among individuals from several moose populations in Alaska. In the Nelchina Basin of south-central Alaska, individual moose movements varied by months both in the initiation and the duration of winter migration (Van Ballenberghe, 1977). Snow depth was an important factor that influenced winter migratory behavior in that population. Cows with calves tended to migrate to wintering grounds earlier than did males and cows without calves (Van Ballenberghe, 1977). During spring in the Nelchina Basin, the initiation of migration varied substantially between individuals, but all individuals migrated quickly once they started moving (Van Ballenberghe, 1977). Individual moose in south-central Alaska (GMU 13) also initiated migration to wintering areas at very different times, ranging from mid-August to mid-February (Ballard et al., 1991). Moose in GMU 13 exhibited more variation in spring migration than Nelchina Basin moose did (Ballard et al., 1991). Dates of spring migration ranged from March through mid-July; during some years, moose remained on the winter range for calving. Subsequent movement to the summer range in mid-summer seemed related to plant development (Ballard et al., 1991).

Moose in different areas of Alaska were found to migrate different distances seasonally and have different annual home range sizes (Ballard et al., 1991; Gillingham and Klein, 1992; MacCracken et al., 1997b) (Table 2). Moose on the Seward Peninsula of northwest Alaska migrate up to 80 km seasonally (Gillingham and Klein, 1992). In south-central Alaska, the distance between winter and summer ranges of migratory moose averaged 48 km, and ranged from 16 to 93 km (Ballard et al., 1991).

Moose use of seasonal home ranges is traditional (Ballard et al., 1991). In south-central Alaska GMU 13, only one of 101 radio-collared female adults dispersed from their traditional home range during a 10-yr study period (Ballard et al., 1991). During the fall of 1978, that female relocated 177 km from her previous location (Ballard et al., 1991).

In the northern Bristol Bay region, some moose collared in GMU 17A since 2000 have moved westward within GMU 17A and into the southern part of GMU 18 (Woolington, 2008). This is thought to be part of a continued westward expansion into previously unpopulated moose habitat (Woolington, 2008).

Table 2. Mean (range) home range size (km2) for selected moose populations in Alaska.

Study area	Migratory status	Age/Sex	Mean home range size (km^2)			Reference
			Total	Winter	Summer	
Kenai Peninsula	M	Adult/M	137 (56–185)			(Bangs et al., 1984)
	N	Adult/M	52 (34–64)			
	N	Adult/F	127 (25–440)	63 (13–184)	36 (2–152)	(Bangs and Bailey, 1980)
Seward Peninsula	M	Adult	938 (236–1,932)	311 (36–1,393)	324 (41–1,323)	(Grauvogel, 1984)
	N	Adult	218 (91–350)	98 (36–223)	93 (44–150)	
	I	Adult	339 (205–593)	122 (21–334)	210 (60–559)	
South-central	N	F	290 (111–787)	113 (10–430)	103 (23–456)	(Ballard et al., 1991)
	M	F	427 (274–580)	147 (15–375)	263 (60–622)	
Southeast	N	Adult/F	28 (9–51)	11 (3–30)	14 (2–30)	(Doerr, 1983)

Migratory status: M = migratory, N= nonmigratory, and I = intermediate. Data from Hundertmark (2007).

Sexual Segregation and Grouping Behaviors- Bowyer et al. (2003) provide a succinct discussion of sexual segregation in moose, and we paraphrase it here. Sexual segregation is the differential use of space by the sexes outside the mating season (Barboza and Bowyer, 2000) and often includes differential use of habitats and forages. Sexual segregation is especially pronounced in moose and plays a crucial role in their ecology (Bowyer et al., 2001; Miller and Litvatitis, 1992; Miquelle et al., 1992). In Alaska, male and female moose select habitats differently, leading to their spatial segregation throughout most of the year (Oehlers et al., 2011)). Spatial segregation occurs because adult males select habitats with greater forage abundance and females select areas with more concealment cover during winter (Bowyer et al., 2001; Miquelle et al., 1992), while cows with calves select denser cover and are more secretive than other age groups (Peek, 2007). In southeast Alaska, female moose selected habitat that maximized high-quality forage while minimizing predation risk, while male moose selected habitat that provided the highest forage intake (Oehlers et al., 2011). In DNPP, summer habitat selection by adult females also varied, depending on whether or not they had a calf (Miquelle et al., 1992). Females with calves remained solitary and preferred forested habitats, which provided better cover from predators. Such differences in habitat use between the sexes have implications for sampling of moose populations, because it can affect the accuracy of sex and age ratio information obtained by direct observation (Bowyer et al., 2002; Peek, 2007; Peterson, 1955; Pimlott, 1959).

The degree to which Alaskan moose segregate by gender varies by season. In DNPP, sexual segregation is most common in winter, when only 19% of all observed groups had both large males and females (Miquelle et al., 1992). Spatial segregation in that study was most extreme during a deep-snow winter, when only large males could access forage at higher-elevation Jenny Creek due to their larger body size (Miquelle et al., 1992).

The effect of habitat enhancement on sexual segregation was studied in interior Alaska after mechanical crushing of willow stands (Bowyer et al., 2001). In that study, males occurred predominantly on the more open, disturbed area during winter, whereas females and young used older stands of willow, where dense vegetation offered substantial concealment from wolves. Females and young faced a tradeoff between foraging on a greater abundance of food in the disturbed area and a reduced risk of predation in the mature stand (Bowyer et al., 2001).

The way in which moose, either individually or in groups, partition their habitats and associate with other moose can be informative in determining the needs of the various segments of the population (Hundertmark, 2007). Moose have been referred to as "quasi-solitary," and large groups are uncommon (Houston, 1968). The tendency of moose to lead a solitary life or to occur in groups depends on their age, sex, and reproductive status, and varies by season. Molvar and Bowyer (1994) note that Alaskan moose are more gregarious than moose from Eurasia and suggest that the formation of social groups is a recently evolved adaptation in Alaska moose in response to a relative abundance of predators and to relatively open terrain. In DNPP, larger groups ventured farther from cover but were less efficient at foraging due to inter-individual aggression (Molvar and Bowyer, 1994).

Cows with calves are consistently the most solitary members of the population, probably because of predator avoidance (Hauge and Keith, 1981; Hundertmark, 2007; Miquelle et al., 1992). Alaskan female moose with calves are nearly always solitary at the time of birth (Miquelle et al., 1992; Molvar and Bowyer, 1994). Females without calves are more likely than males to be

solitary during the early summer, but they become more gregarious as the summer progresses (Miquelle et al., 1992). In DNPP, during the summer, females without calves were seen alone only 23% of the time (Miquelle et al., 1992). During the months of June through August, male moose in DNPP were consistently gregarious (Miquelle et al., 1992). When in a group, small males were more likely than large males to be in a group that included females, at all times except the rut and post-rut (Miquelle et al., 1992).

In south-central Alaska GMU 13, calves separated from their parents at an average age of 14 months (Ballard et al., 1991). In that study, 33% of yearlings and one two-year old were observed in one to six temporary re-associations with their mothers after their original dispersal. Calves were more likely to re-associate with their mother if she was not caring for a new calf (Ballard et al., 1991).

**Mating and Maternal Behaviors-** Moose in North America have two general forms of mating behavior. In the taiga of Canada, moose have a serial mating system, in which bulls search for cows in heat by traveling widely, while calling and thrashing their antlers (Bubenik, 2007). The bull digs shallow pit holes in which he urinates, but they are randomly located and seldom found on the same spot in successive years. For all cows to be bred during the short three-week mating season, the serial mating strategy requires a relatively high number of bulls. Bubenik (2007) concluded that due to differences in climatic conditions of the periglacial tundra, the tactic of serial mating was replaced by communal or harem mating in tundra moose. Toward the end of August, a prime tundra bull settles in a mating area of about 10 km^2. Rutting areas appear to be traditional (Bubenik, 2007). In early September, bulls begin scent-urinating on trails and in pit holes. Two prime bulls may share a harem when it contains eight or more cows. During the eight to ten days of breeding in the harem, a tundra bull probably can fertilize as many or more cows than the taiga bull does during the entire three-week rut because the tundra bull can mate with each female in his harem without traveling long distances to locate a new female.

Many mammals have evolved seasonal reproductive patterns that ensure adaptation to predictable annual changes in the environment. Moose exhibit marked seasonal changes in reproductive behavior that reflect adaptations to yearly fluctuations in food availability to ensure favorable conditions for rearing young (Schwartz, 2007). This means that moose do not reproduce all year long, but only during one season (autumn). By breeding in the fall, it insures calves are born in spring when forage is high in nutrient quality and the cow has a high probability of producing enough milk to successfully raise the calf. Day length may provide the clue to annual timing of the breeding season. Length of the breeding season is relatively short for moose. Since it is difficult to determine the exact date of breeding under natural conditions, few studies provide detailed information. Researchers with the most robust data sets each concluded that moose exhibit a very well-defined breeding season, as judged by conception dates and the spread of observed breeding (Crichton, 1992; Schwartz and Hundertmark, 1993; Thomson, 1991). The mean date of breeding in British Columbia ranged from October 5 to 10, with a standard deviation of five days (Thomson, 1991). The average day of breeding in Manitoba was 29 September and 93% of all females were bred by 12 October (Crichton, 1992). The average breeding date in Alaska was 5 October, with a range from 28 September to 12 October. There was very little difference among years in all studies, suggesting that photoperiod, rather than weather influences rut timing. Synchrony of the rut has also been observed in DNPP. Over a twelve-year interval, rutting consistently occurred during the brief period from 24 September through 5 October (Van Ballenberghe and Miquelle, 1993).

Moose cows across North America give birth during a relatively short period of time. The peak birthing period occurs from about 15 May through 7 June (Schwartz, 2007). In DNPP, timing of birth in moose was consistent from year to year, despite variation in climate between years (Bowyer et al., 1998). Birth timing exhibited "extreme synchrony" and Bowyer et al. (1998) hypothesized that moose were tracking long-term patterns of climate in the area to time reproduction. Hence, there is concern that moose will be vulnerable to climate change even before extensive changes to vegetation occur (Bowyer et al., 1998).

In DNPP, the primary drivers influencing birth site selection were microclimate, forage abundance and quality, and risk of predation (Bowyer et al., 1999). Birth sites were not re-used, and some females appeared to behave unpredictably shortly before giving birth, perhaps in an attempt to thwart predators (Bowyer et al., 1999). Proximity to human development did not influence birth site selection. Moose preferred birth sites with abundant willow, high visibility to detect predators, and a southeasterly exposure that would be warmer and drier (Bowyer et al., 1999). Bark stripping was common around birth sites, because females seldom travelled more than 100 m from their young and hence rapidly depleted the birth site's forage (Bowyer et al., 1999).

Activity Budgets- Moose spend most of their active life foraging. Seasonal rates of forage intake tend to mimic the cyclic nature of energy metabolism in moose (Regelin et al., 1985), with higher rates of activity and intake in spring and summer and reduced rates during winter. Activity budgets tend to follow a similar pattern. Activity budgets have been studied for DNPP moose during winter (Risenhoover, 1986) and spring/summer (Van Ballenberghe and Miquelle, 1990). DNPP moose exhibited low activity levels from January through April, when they were active, on average, only 27.3% of the time (6.5 h/d) (Risenhoover, 1986). Risenhoover (1986) found that activities associated with resting and foraging constituted 99.3% of the time of DNPP moose in winter. In contrast, Miquelle et al. (1992) found that small males in DNPP spent some of their active time engaged in social behavior during winter. In winter and early spring in DNPP, moose exhibited a polyphasic pattern alternating between foraging and bedding, with about six cycles per 24 hours (Risenhoover, 1986).

Following their relative inactivity in winter, DNPP moose increased their metabolic rate in April, as evidenced by the onset of antler development in males and increased mobility of cows (Risenhoover, 1986). Activity increased during May to a peak in early June, then began to decline until mid-August (Van Ballenberghe and Miquelle, 1990). DNPP moose were active 12.8 h/d at the peak, and activity had declined to 9 h/d by late summer (Van Ballenberghe and Miquelle, 1990). In summer DNPP moose spent about equal amounts of time feeding, resting and ruminating during each 24-h period (Van Ballenberghe and Miquelle, 1990). When comparing winter activity budgets (Risenhoover, 1986) to summer activity budgets (Van Ballenberghe and Miquelle, 1990) in DNPP, large differences were observed (Table 3).

Table 3. Moose activity budgets in winter[1] and spring/summer[2] in Denali National Park and Preserve (averages)

Activity Parameter	Winter	Spring/Summer
Total active time/day (hr)	6.5	10.1
Total resting time/day (hr)	17.5	13.9
# Activity bouts/day	5.7	8.2
Duration of activity bouts (min)	68	73
Duration of resting bouts (min)	178	97
Foraging time/day (hr)	4.9	7.5
Rumination time/day (hr)	11.7	6.7

1= "Winter" is January through April; data from Risenhoover 1986
2="Spring/Summer" is 1 May through 15 August; data from Van Ballenberghe and Miquelle (1990)

On the Seward Peninsula of northwestern Alaska, moose winter activity time allotments were 43.2% feeding, 42.8% bedding, 8.4% walking, 4.4% standing, and 1.2% other (Gillingham and Klein, 1992). Walking time was far greater than reported during winter in DNPP (< 1%) (Risenhoover, 1986). Gillingham and Klein (1992) attributed this difference to Seward Peninsula moose using the Kuzitrin River as a feeding and movement corridor during winter. The use of a narrow, linear feature, such as a river bottom, means that a moose needs to travel farther up and down the river to obtain food, as opposed to feeding in a large, non-linear area. There are at least two other differences between DNPP moose and Seward Peninsula moose. While there is an abundance of predators in DNPP (wolves and bears), there are no predators of moose on the Seward Peninsula in winter (Gillingham and Klein, 1992). Also, moose activity was highly synchronized during mid-afternoon in late April on the Seward Peninsula; presumably due to heat stress (Gillingham and Klein, 1992). In contrast, there was no significant correlation between mean daily temperature and daily activity level in DNPP during winter (Risenhoover, 1986).

On the Copper River Delta, inactive bout duration of moose was shortest on the west delta, which had the highest estimates of forage abundance and quality among the three areas studied (MacCracken et al., 1997a). It was suggested that the relative duration of inactive bouts might be useful as an index of habitat quality for moose.

Interspecies Interactions

Boer (2007) provided an excellent review of the interspecific relationships between moose and other species. Interspecific interactions between moose and other species take on one or more of the following general forms: competition, parasite-mediated competition, predation, and commensalism (Boer, 2007). Due to the diversity of habitats, species combinations, and abundance of sympatric species, a variety of competition mechanisms operate throughout moose range. Of the interspecific interactions possible, competition is the most obvious one influencing moose habitat use and distribution (Boer, 2007). Throughout their North American range, moose compete with an array of other ungulate species. However, in the Nushagak and Kvichak watersheds, caribou are the only other ungulate species abundant enough to consider. Direct competition between moose and caribou appears limited and insignificant (Davis and Franzmann, 1979). Food preferences of moose and caribou coincide to some degree, but the diet of caribou appears to be more specialized. Caribou consume forbs and deciduous vegetation and lichens in

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winter (Darby and Pruitt, 1984; Servheen and Lyon, 1989). Moose primarily consume browse, but also use forbs and deciduous vegetation during summer (Dodds, 1960; Eastman and Ritcey, 1987).

As reviewed by Boer (2007), in multi-prey systems, moose and caribou populations may influence each other indirectly. Increasing moose numbers in western and central portions of DNPP have resulted from increased availability of caribou as alternate prey for wolves (Singer and Dalle-Molle, 1985). In the eastern section of that park, migrating caribou were available as prey for only a brief period of time, and therefore, they were not a particularly important factor of the area's prey base. In that area, moose populations have declined. Moose are the primary prey of wolves in other areas of Alaska as well (Gasaway et al., 1983), although others have attributed an increase in moose numbers in northern Alaska to a preference by wolves for caribou (Coady, 1980).

Interspecies population dynamics have been studied in several areas of Alaska with multiple predators and multiple prey species. These relationships can be quite complex and can vary based on both abiotic and biotic factors within the ecosystem. None of the formal scientific interspecies studies reviewed here were conducted in the Nushagak and Kvichak watersheds.

In Alaskan ecosystems with multiple predators, bears were responsible for more moose calf kills than were wolves. Black bears can be significant predators of moose calves (Franzmann et al., 1980). Of 47 radio-collared neonatal calves on the Kenai Peninsula, black bears killed 34%, whereas brown bears and wolves each killed 6% (Franzmann et al., 1980). In the western Interior, near McGrath, black bears were also the dominant source of predation mortality of calves during six out of seven years studied; wolves and brown bears were secondary predators in that system (Keech et al., 2011). In contrast, brown bears were the primary predators of moose calves in a south-central Alaska study, causing 73% of calf mortality (Ballard et al., 1991). Brown bears were also the primary predator in east-central Alaska (GMU 20E), where 79 to 82% of radio-collared moose calves died by the age of eleven months (Gasaway et al., 1992). In that study, 52% of moose calves were killed by brown bears, 12 to 15% of calves by wolves, and 3% by black bears.

Several studies have compared the causes of calf mortality in the nutritionally unproductive 1947 burn and in the productive high-quality habitat of the 1969 burn on the Kenai Peninsula, Alaska (Franzmann and Schwartz, 1986; Schwartz and Franzmann, 1989; Schwartz and Franzmann, 1991). Black bears killed 34 and 35% of the calves, respectively, whereas wolves and brown bears killed 5 to 13%, respectively. Total calf mortality from all causes ranged from 51 to 55%. Moose densities were four times greater in the 1969 burn area ($370/100$ km^2) and the population was increasing, whereas the population in the 1947 burn was about $100/100$ km^2 and declining. The investigators concluded that habitat quality had a significant impact on reproductive rate and population growth. The moose population in high-quality habitat (1969 area) was capable of sustaining this level of predation and continued to grow, whereas the population in poor habitat (1947 area) was not.

Wolves appeared to select for moose calves in some areas and seasons in Alaska, but not in others. In south-central Alaska, moose calves were taken in proportion to their abundance in the overall population during May through October (Ballard et al., 1987). In contrast, during November through April in that study, wolves preyed on moose calves selectively. During those months calves were only 12 to 20% of the moose population, but they consisted of 40% of moose kills by wolves (Ballard et al., 1987). During autumn in northwest Alaska, wolves displayed a lack of selectivity for moose calves, which were killed in proportion to their relative abundance within the

population (Ballard et al., 1997). On the Kenai Peninsula, wolves killed mostly moose calves (47%), yearlings, and older adults (Peterson et al., 1984). Half of moose adults killed by wolves during that study were more than twelve years of age. Wolf predation on moose calves was highest during the winter with deepest snow, and calves killed after 1 January were commonly malnourished, with bone marrow fat content ≤10%.

In east-central Alaska (GMU 20E), predation was the primary cause of non-hunting deaths for yearling and adult moose (Gasaway et al., 1992). Of 46 such moose that died from 1981 through 1987, 89% were killed by brown bears or wolves, 9% died from antler wounds or locked antlers, and 2% drowned. Peterson et al. (1984) examined the incidence of debilitating conditions among 109 wolf-killed adult moose on the Kenai Peninsula. They found that 20 such moose had moderate or severe periodontitis, 14 had arthritis, one had a broken leg, and one had a leg wedged between trees. Of 40 wolf-killed adult moose assessed for bone marrow fat content, four had levels ≤20%, indicating severe malnutrition (Peterson et al., 1984).

Wolves in different regions in Alaska displayed different relative preferences for moose and caribou as prey. In south-central Alaska, moose were the primary prey of wolves, constituting 38% of observed kills, while caribou was the second most important prey at 21% (Ballard et al., 1987). In northwest Alaska, caribou was the preferred prey of wolves (Ballard et al., 1997). In January through April 1988, when caribou were abundant, 92% of observed ungulates killed by wolves were caribou. In contrast, in 1989 and 1990 when caribou were less abundant, they constituted 11% and 48% of observed ungulate kills, respectively (Ballard et al., 1997).

Estimated kill rates for wolf packs on the Kenai Peninsula varied from one moose/3.1 days to one moose/21.4 days (Peterson et al., 1984). The average kill interval in winter for Kenai wolf packs with more than two members was 4.7 days. In 38 wolf-moose encounters observed on the Kenai Peninsula, wolves succeeded in killing only two of the moose (Peterson et al., 1984).

Ballard et al. (1997) speculates that the recent occurrence of moose (since the 1940s) in northwest Alaska has altered the historical migratory patterns of wolves in that area. There is evidence that wolves in northwest Alaska used to migrate with the caribou herds, but now they do that only when alternate prey (moose) numbers are insufficient.

Mortality, Productivity, and Survivorship

Understanding the dynamics of a population requires knowledge of how many individuals it contains, how fast it is increasing or decreasing, its rate of production of young, and its rate of loss through mortality (Van Ballenberghe and Ballard, 2007). Moose populations increase by the addition of calves born to the population each year and decrease by the loss of animals. Death can occur from the moment of birth. Moose die from a variety of causes including hunting, predation, starvation, accident, drowning, vehicle collision, parasites, and disease. Mortalities are generally divided into two major categories: human-caused or natural. Moose populations are adaptable to artificially disturbed habitats, and therefore are often found in close proximity to roads, major highways, and railways. But this association is far from compatible (Child, 2007). In populated areas of Alaska a large number of moose are killed each year by collisions with motor vehicles and trains (Bowyer et al., 2003; Child, 2007). For example, from 1963 to 1990, 3,054 moose were killed on the Alaska Railroad, with annual losses ranging from seven to 725 (Modafferi, 1991). In the severe winter of 1989–1990, deep snow caused more moose to travel on roads and railroads

and fatalities thereon exceeded the previous record by more than 100 animals. In the Willow-Talkeetna area during the same winter, the number of railroad kills represented a 70% loss from the resident population (Schwartz and Bartley, 1991). Other sources of mortality include sport and subsistence hunting and poaching (Woolington, 2004).

Prime adult moose tend to have very high rates of survival because they are not as vulnerable to natural causes of mortality when compared to younger (calves) and older age classes. Survival rates are generally estimated by radio collaring individuals and following them for some period of time (Van Ballenberghe and Ballard, 2007). Ballard et al. (1991) provided data on mean annual survival rate from a sample of radio-collared adult female moose during a ten-year period. From 25 to 80 moose per year were followed in a study area where hunting of cows was prohibited. Annual survival rates were estimated at 94.8%. Data from yearling females spanned four years with two to 22 individuals per year collared, and annual survival rates averaged 95.1%. Annual survival of yearling and adult males averaged 75.4 and 90.9% respectively, with hunting the major mortality factor. On the Kenai Peninsula, researchers followed 51 radio-collared females for six years and reported a 92% annual survival rate (Bangs et al., 1989). Survival of cows aged 1 to 5 years was estimated at 97% and 84% for females aged 16 to 21 years. Hunting was not a significant cause of mortality of the study population. As reported by Van Ballenberghe and Ballard (2007), various other studies using radio-collared moose have reported annual survival rates of adults ranging from 75 to 94%, depending upon the extent of human hunting. In general, starvation and wolf predation during severe winters causes the greatest mortality in older age classes (Ballard et al., 1991; Bowyer et al., 2003); moose weakened from starvation are particularly vulnerable to wolf predation. Bull moose occasionally wound each other during the rut and die from these wounds (ADF&G, 2011d).

As reviewed by Van Ballenberghe and Ballard (2007), hunting is a major limiting factor of many moose populations throughout the world. In fact, hunting pressure can reduce moose population density (Crete et al., 1981). In Quebec, where natural mortality apparently was low, harvest rates as high as 25% were reported (Crete, 1987). Moose harvest rates ranging from 2 to 17% have also been reported for various other parts of North America (Crete, 1987). In concert with other factors, including severe winters, high harvest rates have contributed to moose population declines in Alaska (Gasaway et al., 1983). In addition, hunting can significantly reduce the number of bulls, perhaps sufficiently to reduce the level of first-estrus conception (Bishop and Rausch, 1974). When, due to heavy hunting pressure, there are fewer than ten bulls per 100 cows, some cows simply may not encounter a bull early in the mating season. Breeding early in the mating season means the rut would be synchronous and calving would therefore be synchronous. If a cow mates late in the breeding season, the result would be later calving in the spring. In some European environments, where severe winters, predation and nutritional stress are absent, moose harvest as high as 50% of the winter population is sustainable (Cederlund and Sand, 1991). Most North American moose populations harvested at this rate would decline sharply. In nearly all areas where hunting is legal, harvest is managed under sustainable principals, so hunting mortality seldom results in unintended population declines (Timmerman and Buss, 2007).

Within the Nushagak and Kvichak watersheds both hunter numbers and moose harvest have increased. Correlated to a four-fold increase in moose hunters in GMU 17 from 1983 to 2006 (from 293 to 1,182), reported moose harvest tripled (from 127 to 380). In GMU 17B (the upper Nushagak watershed), the reported harvests for the past five years, when data were available, ranged from 113 to 183, with a mean annual harvest of 149 moose. In GMU 17C (the Togiak

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watershed), the five-year mean annual harvest was 224, with a range of 193 to 251 (Woolington, 2008). Hunters must harvest moose with antler spreads of no less than 50 inches. The largest antlers reported exceeded 69 inches.

Juvenile moose tend to die at higher rates than adults. Calves are typically the most vulnerable age class. Calf moose mortality can be divided into two general time periods when mortality is highest: from birth to about six months of age, and from about nine months to one year of age (Van Ballenberghe and Ballard, 2007). These periods correspond roughly to particular vulnerabilities, specifically, to bear and wolf predation in the first period and hunting (in some areas), wolf predation, and winter starvation in the second period. According to Van Ballenberghe and Ballard (2007), neonatal mortality varies greatly, depending on several factors, most notably the extent of predation. Several studies of radio-collared moose calves have documented that predators may account for up to 79% of newborn deaths and that survival during the first eight weeks of life may be as low as 17% (Ballard et al., 1981; Ballard et al., 1991; Franzmann et al., 1980; Gasaway et al., 1992; Larsen et al., 1989; Osborne et al., 1991). Further losses during the first year of life may result in annual survival rates as low as 10% (Van Ballenberghe and Ballard, 2007). In south-central Alaska, Ballard et al. (1991) observed that brown bears caused the majority of natural death of calves younger than five months of age, whereas, on the Kenai Peninsula, Franzmann et al. (1980) documented that black bears were the greatest cause of moose calf mortality.

Moose breed in late September to early October (Van Ballenberghe and Miquelle, 1993) and adult females give birth to one or two (twin) calves in late May–early June each year (Schwartz, 2007; Testa et al., 2000). Production of moose calves is the result of a complex chain of biological processes including estrus cycles, rutting behavior, fertilization, gestation, pre-partum events and birth (Boer, 1992; Schwartz, 2007; Van Ballenberghe and Ballard, 2007). Fecundity, or productivity of individual moose, is related to sexual maturation and a broad array of ecological factors affecting food supply, forage quality, and weather that affect the physiological status of females. These factors influence ovulation, pregnancy rates, litter size, and fetal sex ratios. Ultimately, fecundity and subsequent survival of young determines recruitment rates and population trends, which are important factors in moose population dynamics.

Reproductive tract studies have shown that female moose do not ovulate during the mating season in the first year of life and therefore do not produce calves as yearlings. Cows may or may not breed in their second year, depending on body mass (Saether, 1987). Most cows are sexually mature at around 28 months of age and females continue to breed to the end of their life span at around 18 years of age (ADF&G, 2011d; Schwartz, 2007). Litter size in moose ranges from one to three (Peterson, 1955), but litters greater than two are rare (Coady, 1982). Body condition of female moose (as influenced by habitat quality) has correlated strongly with twinning rates in several diverse moose populations (Franzmann and Schwartz, 1985). In an area known to contain abundant high-quality food resources on the Kenai Peninsula, up to 70% of cows with calves one year had twins the next year. This contrasts to other populations, in which twinning rates as low as 5% were reported (Houston, 1968; Markgren, 1969; Pimlott, 1959), but some of the estimates may have considered post-natal mortality. The data suggest that twinning rates exceeding 40 to 50% are uncommon for moose populations strongly limited by nutrition. Twinning frequency is a good indicator of cow health condition and habitat quality (Dodge et al., 2004). Calves that survive predation from bears in the summer wean in August, but will remain with their mother until the

next calf is born the following spring (Schwartz, 2007), or for an additional year if no new calf is born (Testa, 2004).

Population, Subpopulations, and Genetics

The number of animals in a population is one measure of abundance, but is only useful when the geographic boundaries of an area are well defined, because that allows biologists to estimate density (the number of individuals per unit area), which is a more robust parameter. Moose population densities were compared by Gasaway et al. (1992) over very large areas (>2000 km^2) of generally continuous moose habitat across a broad area of Alaska and the Yukon Territories. They noted that smaller sites exhibited high variability in prey and predator densities and in habitat quality, making it more difficult for realistic comparisons. They focused their comparisons on the post-hunt, early winter season thereby enhancing comparability further. The mean density of moose from 20 populations was estimated at 0.148/km^2 (range 0.045–0.417/ km^2) in areas where predation was thought to be a major limiting factor of moose. Densities of 16 other populations in the same area, where predation was not limiting, averaged 0.66 moose/km^2 (Van Ballenberghe and Ballard, 2007). Ballard et al. (1991) provided 29 moose density estimates from Alaska, including some populations studied by Gasaway et al. (1992); they ranged from 0.05 to 1.24/ km^2.

ADF&G estimates the total population of moose in Alaska at 175,000 to 200,000 animals (ADF&G, 2011d). The 2004 population estimate for the study area of the Nushagak and Kvichak watersheds was 8,100 to 9,500 moose (Butler, 2004; Woolington, 2004). This estimate was based on population data from ADF&G GMUs 17B, 17C, 9B and less than half the area of GMU 9C, outside the Katmai National Park (Figure 3).

Moose are relatively new inhabitants in the Bristol Bay area, possibly having migrated into the area from middle Kuskokwim River drainages during the last century (Woolington, 2004). Moose were either not present or were sparse in the northern Bristol Bay area until the turn of the twentieth century, and even then the moose population did not increase until three decades ago (Butler, 2004; Woolington, 2004). Suspected reasons for low moose populations in the Bristol Bay region are heavy hunting pressure, particularly on female moose in the western part, and bear predation in the eastern part (Butler, 2004; Woolington, 2004). Over the last 25 years, managed harvesting, predator control, an increase in caribou herds as an alternative predator food source, and consecutive mild winters have led to an increase and expansion of the moose population westward (Butler, 2004; Woolington, 2004).

The largest moose population in the study area is in the Nushagak drainage; the upper watershed (GMU 17B) has an estimated 2,800 to 3,500 moose, while the lower drainage (GMU 17C) has an estimated 2,900 to 3,600 moose (ADF&G, 2011d). These moose comprise about 73% of the total moose in the Nushagak and Kvichak watersheds. The Nushagak drainage has large, healthy areas of riparian habitat, a major component of which is felt-leaf willow, a preferred browse species (Bartz and Naiman, 2005). The number of moose in the Kvichak watershed was estimated at 2,000 in GMU 9B, and less than 400 moose in the portion of GMU 9C outside Katmai National Park (Butler, 2008).

Fall trend counts have been notoriously unreliable in providing consistent data on moose populations in GMU 17 (Woolington, 2008). Suitable survey conditions, including complete snow

coverage, light winds and moose movements onto winter range rarely occur before antler drop. Regular population estimation surveys of portions of the unit during late winter provide the best population information; unfortunately they do not provide reliable information on sex and age composition.

Moose population estimates in the northern Bristol Bay area are produced by a spatial statistics stratification model, which uses harvest ticket data from sport and subsistence hunters (Butler, 2004; Woolington, 2004). The ADF&G, Division of Subsistence suspects there is a considerable unreported subsistence harvest as well as illegal harvest occurring in some regions of Alaska (ADF&G, 2011d). Illegal harvest of moose in Unit 17 was probably more of a problem in the past than during recent years. Unit residents used to actively pursue moose with snow machines during the winter and spring, when both male and female moose were taken. Attitudes have changed following considerable efforts by State and federal management agencies, working with local communities to help hunters see the benefits of reducing illegal moose kills. It is now common to see moose near local villages throughout the winter (Woolington, 2008).

Human Use (Subsistence, Recreation)/Interaction/Management)

In Alaska 7,400 moose were harvested in 2007. Residents harvested 6,750 moose and 685 were taken by non-resident hunters (ADF&G, 2011d). The harvest of 7,400 moose yields approximately 3.5 million pounds (1,587,573 kg) of meat.

Harvest records from ADF&G for 1983 to 2002 indicate that GMU 9 and 17 provided 7% of the total moose harvest in Alaska (BLM 2007). According to ADF&G, Division of Subsistence (http://www.adfg.alaska.gov/sb/CSIS/) local subsistence hunters from King Salmon, Naknek, and South Naknek harvested 19 moose in GMU 9B in 2007; total meat harvested was estimated at 10,206 pounds (4,629 kg). In unit 17B, local residents from Igugig, Koliganek, and New Stuyahok harvested 88 moose in 2005 (last year of available data); total meat harvested was estimated at 48,208 pounds (21,867 kg). Likewise, residents from Naknek and South Naknek harvested 4 moose from unit 17C with a total of 5,357 pounds (2,430 kg) of meat. In total, subsistence moose meat accounted for 63,771 pounds (28,987 kg) of meat with an average of 128 pounds (158 kg) harvested per household (Table 4).

Moose are an important subsistence food species for people residing in the area served by the Bristol Bay Area Health Corporation (Ballew et al., 2004). In a survey about traditional food consumption conducted in 2002, 86% of respondents from that region reported consumption of moose meat within the past year, at a median per capita consumption rate of five pounds (2.3 kg) per year (Ballew et al., 2004). Moose was the third greatest subsistence source of meat to residents of that region; residents reported eating more salmon and caribou than moose. Subsistence statistics (Table 4) also suggest that, on average, a high percentage of individuals from villages in the area (38%) attempted to harvest a moose, with about 20% succeeding. Additionally, about 24% of individuals reported sharing their moose with others, while 44% received meat from others.

In addition to being a source of subsistence meat, moose also contribute to the local economy, through jobs created as a result of non-resident hunters seeking a remote fly-in or boat-in experience to take a trophy moose.

Table 4. Subsistence statistics for moose harvest in Alaska Dept. of Fish and Game, game management units (GMU) 9B, 17B, and 17C.

GMU	Community name	Study year	Using (%)	Attempted harvest (%)	Successfully harvested (%)	Shared meat (%)	Received meat (%)	Reported harvest (#)	Estimated harvest (#)	Reported harvest lbs	Estimated harvest lbs	Mean harvest/ household (#)
09B	King Salmon	2007	33	31	10	10	24	5	9	2,700	4,849	55
09B	Naknek	2007	48	23	5	5	47	4	10	2,160	5,357	29
09B	South Naknek	2007	29	24	0	0	29	0	0	0	0	0
17B	Igiugig	2005	100	50	42	75	67	6	6	3,240	3,510	270
17B	Koliganek	2005	86	68	50	54	46	16	24	8,640	12,960	309
17B	New Stuyahok	2005	94	65	51	43	65	30	58	16,200	31,738	331
17C	Naknek	2007	48	23	5	5	47	4	10	2,160	5,357	29
17C	South Naknek	2007	29	24	0	0	29	0	0	0	0	0
Total										35100	63771	
Mean			58	38	20	24	44					128

(Data are from 2005 or 2007 and represent the most recent information available.) (http://www.adfg.alaska.gov/sb/CSIS/)

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BARREN GROUND CARIBOU

Introduction

Alaska is currently home to 31 herds of wild caribou (*Rangifer tarandus granti*), with a combined population of approximately 760,000. Caribou herds are defined by their traditional and predictable use of calving areas that are separate and distinct from the calving grounds of other herds (Skoog, 1968). Use of other seasonal ranges is variable and less traditional. Caribou from different herds may overlap on seasonal ranges other than calving areas (Cameron et al., 1986). Historically, most caribou herds have fluctuated widely in numbers and in use of range (Skoog, 1968).

Adult bull caribou in southwestern Alaska usually weigh between 350 and 450 lbs (159 to 182 kg), while females weigh between 175 and 225 lbs (80 to 120 kg) (ADF&G, 1985). Body weight can vary with environmental and nutritional conditions (Cameron, 1994; Valkenburg et al., 2003). Caribou are the only members of the deer family in which both males and females grow antlers. Bulls begin to shed the velvet on their antlers between late August and early September, marking the start of breeding season. The largest bulls begin shedding their antlers in late October, with smaller bulls losing their antlers later in the winter. Females shed velvet in September (Skoog, 1968). Pregnant females usually keep their antlers until the calving season in the spring, while non-pregnant females lose their antlers about a month before calving begins. Some females never grow antlers (Whitten, 1995). Caribou populations throughout the Bristol Bay region have declined recently and body weights and antler sizes are now relatively low. In the past the area produced large-bodied animals with record book antlers (Valkenburg et al., 2003).

Population History of Caribou in the Upper Bristol Bay Region

Historical accounts from the early 1800s indicate that caribou were plentiful in the Bristol Bay region. There may have been a large herd that ranged from Bristol Bay across the Kuskokwim and Yukon deltas all the way to Norton Sound. By the late 1800s caribou throughout this area had declined dramatically. Caribou numbers may have increased in the early 1930s, but were declining again by the late 1930s. Domestic reindeer were brought to the Bristol Bay region in the early 1900s, but by the 1940s, reindeer herds were widely neglected and either died out or were assimilated into wild caribou populations (Skoog, 1968; Woolington, 2009a). Caribou in the Nushagak drainage remained relatively scarce into the 1970s, at about 10,000-15,000 animals (Woolington, 2009a).

Over the past thirty years, caribou herds in southwest Alaska have continued to undergo significant changes in population numbers. The Nushagak and Kvichak drainage basins are now used primarily by caribou from the Mulchatna herd. The Mulchatna herd grew rapidly during the 1980s and 1990s, from a population of about 18,600 animals in 1981 to a peak of approximately 200,000 in 1997. By 1999 the Mulchatna herd had declined to 175,000 and it continued to decline, to approximately 30,000 in 2008 (Valkenburg et al., 2003; Woolington, 2009a). As the Mulchatna herd grew, it overlapped with and eventually assimilated the much smaller Kilbuck (or Qavilnguut) herd that formerly ranged infrequently into the western part of the Nushagak

drainage. By the late 1990s the Kilbuck herd had ceased to function as a distinct population (Woolington, 2009a).

The Northern Alaska Peninsula herd recovered from a population low of about 2,000 in the late 1940s to about 20,000 in 1984. The population remained at about 15,000 to 19,000 through 1993, but has since declined steadily to about 2,000 to 2,500 today (Butler, 2009a). For the most part, caribou of the Northern Alaska Peninsula herd remain well south of the Kvichak drainage. However, from 1986 to 2000 many caribou from the Northern Alaska Peninsula herd wintered in the Kvichak drainage, south of Lake Iliamna (Butler, 2009a). In the late 1980s and early 1990s, the Kvichak drainage was also used by far greater numbers (up to 50,000) of Mulchatna caribou (Woolington, 2009a). The two herds always returned to their traditional calving and summer ranges and remained distinct (Butler, 2009a; Hinkes et al., 2005; Woolington, 2009a).

The Nushagak Peninsula herd is a small population that was established in 1988, when caribou from the Northern Alaska Peninsula herd were translocated to the Nushagak Peninsula south of the Nushagak River delta, on the west side of upper Bristol Bay. The Nushagak Peninsula had been unoccupied by caribou for approximately 100 years (Hotchkiss, 1989; Paul, 2009). The Nushagak Peninsula herd grew rapidly after its introduction, from 146 caribou to over 1,000 caribou in 1994. Growth continued at a slower rate to about 1,400 caribou in 1997. Population density peaked at approximately 1.2 caribou per km^2. During the next decade, calf recruitment and adult female survival decreased and the population declined to 546 caribou in 2006 (Aderman, 2009). The population remained at about 550 caribou until 2009 and then increased to 801 by 2011 (Aderman and Lowe, 2011).

Habitat

Seasonal Preference- Spring calving grounds tend to be in open tundra areas or high and rugged mountains. Predator densities are often lower in such areas, but large caribou herds can also calve at high densities in sparsely forested terrain, where their sheer numbers and synchronized timing of births can swamp the effects of predators (ADF&G, 1985; Skoog, 1968).

During summer (mid-June to mid-August), caribou feed in open tundra, mountain, or sparsely forested areas. To avoid harassment from mosquitoes and other insects, caribou often gather on windswept ridges, glaciers, lingering snow drifts, gravel bars, elevated terrain, cinder patches, and beaches. Caribou near the coast may also avoid insects by standing head down and motionless on mudflats (ADF&G, 1985; Skoog, 1968).

In winter caribou often feed in forested areas, especially where there are spruce-lichen associations. In addition to forested areas, caribou can also be found along ridge tops, on frozen lakes and in bogs during winter (ADF&G, 1985; Skoog, 1968).

Food Habits

Spring- From mid-April to mid-June, caribou usually eat catkins of willow (*Salix alaxensis, S. planifolia spp. S. pulchra, and S. glauca*), grasses and sedges (*Carex bigelowii, C. membranacea, C. podocarpa*, and *Eriphorum vaginatum*). They also consume fruticose lichens, resin birch (*Betula glandulosa*), dwarf birch (*B. nana*), and horsetails (*Equisetum* spp.)(ADF&G, 1985; Skoog, 1968).

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Summer- From mid-June to mid-August, caribou typically consume willow leaves, resin birch, and dwarf birch, as well as sedges and grasses, especially grasses from the genera *Alopecurus*, *Arctagrostis*, *Dupontia*, *Festuca*, *Poa*, *Puccinellia*, *Calamagrostis*, and *Hierochloe*. They also eat horsetails, legumes (*Astragalus umbellatus*, *Lupinus arcticus*, *Hedysarum alpinum*, and *Oxytropis nigresens*), and forbs such as *Gentiana glauca*, *Swertia perennis*, *Sedum roseum*, *Antennaria monocephala*, *Artemisia arctica*, *Epilobium latifolia*, *Pedicularis* spp., *Petasites frigidus*, *Polygonum bistorta*, *Rumex arcticus*, and *Saxifraga* spp. (ADF&G, 1985; Skoog, 1968).

Fall- Caribou feed on grasses, sedges, and lichens throughout the fall. They also feed on willow and water sedge (*Carex aquatilis*), if they are available (ADF&G, 1985). Caribou also feed on mushrooms, when available (Skoog, 1968).

Winter- Caribou winter diets consist primarily of lichens (especially *Cladonia* spp. and *Cetraria* spp.), with smaller amounts of sedges and grasses, as well as horsetails, and the tips and buds of willows and dwarf shrubs (e.g., *Vaccinium uliginosum*). They may consume vegetation in muskrat pushups during winter, as well as aquatic vegetation in poorly drained coastal plains (ADF&G, 1985; Skoog, 1968).

Behavior

Seasonal Range Use and Migrations- Some caribou herds travel long distances between summer and winter ranges, in order to find adequate sources of food and bear their calves in areas relatively free of predators (Bergerud, 1996; Griffith et al., 2002; Skoog, 1968; Whitten et al., 1992). Physical features on the landscape influence caribou migration routes. Caribou must negotiate around open seawater, large lakes, swift rivers, rivers with floating ice, rocky regions in high mountains, volcanic cinder patches, glaciers, and burns. Features such as frozen lakes and rivers, as well as ridge tops, eskers, streambeds, and hard-surfaced snow drifts aid caribou during winter migration (ADF&G, 1985). Since the 1980s, calving areas, other seasonal ranges, and migration routes of the Mulchatna herd have varied widely. The Mulchatna herd has ranged extensively throughout most of the Nushagak and Kvichak watersheds, but caribou from this herd also spend much of their time to the north in the Kuskokwim River drainage (Woolington, 2009a).

In contrast to most other migratory caribou herds, the Mulchatna herd does not use the same traditional calving ground annually, although its calving areas have remained distinct from those of any other herds. The Mulchatna herd calved in the Bonanza Hills area of the upper Mulchatna River watershed during the 1980s. In 1992, calving shifted west to the Mosquito River drainage in the upper Mulchatna watershed. From 1994 to 1999 calving generally occurred in the upper Nushagak River watershed. From 2000 to 2002 calving was split between the lower Nushagak watershed and the South Fork of the Hoholitna River, in the Kuskokwim drainage. In 2003 and from 2005 to 2008, calving occurred near Kemuk Mountain in the Nushagak drainage, as well as near the South Fork of the Hoholitna in the Kuskokwim drainage. In 2004 calving was widespread, from Dillingham in the Nushagak watershed, north to the Holitna and Hoholitna Rivers in the Kuskokwim drainage (Woolington, 2009a).

The Mulchatna herd often ranges widely across the Nushagak drainage during summer and fall, but also frequently uses areas to the north and west, in the Kuskokwim Mountains. During the 1980s much of the Mulchatna herd wintered north and west of Lake Iliamna, in the Kvichak drainage. In the 1990s most wintering shifted to the Kuskokwim Mountains. For the past decade part of the herd has wintered in the Nushagak and Mulchatna watersheds while part of the herd has wintered in the Kuskokwim watershed. In 2006/2007 and 2007/2008, up to 20,000 Mulchatna caribou wintered in the lower Nushagak and Kvichak valleys, with some going as far south as the Naknek valley in 2006/2007 (Woolington, 2009a).

Mulchatna caribou are often widely dispersed during movements between seasonal ranges. In accordance with the highly variable locations of seasonal ranges, migration tends not to follow the same routes from year to year (Woolington, 2009a).

Historically, the Northern Alaska Peninsula herd has spent most of its time in areas from the Naknek drainage to the south, far removed from the Kvichak and Nushagak watersheds. From about 1986 through 2000 many caribou from the Northern Alaska Peninsula herd did winter in the Kvichak drainage, south of Lake Iliamna, but since 2001, only a single radio-collared caribou from this herd has wintered north of the Naknek River (Butler, 2009a).

Like many small caribou herds, the Nushagak Peninsula herd is sedentary and spends the entire year on the Nushagak Peninsula, although a few caribou from this herd have made short forays off the Peninsula (< 20 km and for < 1 month) (Aderman and Woolington, 2001). So far, there has been no overlap between the Nushagak Peninsula herd and much larger migratory Mulchatna herd.

Response to Disturbance- Industrial activities impact caribou by hindering or altering their movements or displacing them from preferred habitats. Barren-ground caribou on the North Slope of Alaska have avoided development such as exploration wells (Fancy, 1983) and linear developments such as roads and pipelines (Dau and Cameron, 1986) by distances of 2 to 5 km. Establishment of extensive, densely packed development with interconnecting road networks, high levels of traffic, aircraft activity, and ongoing construction or production activity around the Prudhoe Bay oilfields has resulted in general displacement of caribou from some areas (Griffith et al., 2002). Avoidance and displacement are most prevalent among females with young calves (Cameron and Whitten, 1980; Cameron et al., 1979; Griffith et al., 2002). Similarly, woodland caribou in Canada typically avoided areas near mining sites by 1 to 5 km (Weir et al., 2007). Mining activities had the highest impact on caribou during calving season. Larger groups and females with young typically avoided mining sites more often than smaller groups and caribou without young (Weir et al., 2007). Weir et al. (2007) identified corridors such as roads and seismic lines as the greatest development impact on caribou because they increase the chance of encounters with humans and predators. The large Red Dog Mine in northwestern Alaska has had only limited and localized effects on caribou movements and distribution, in part because the mine occupies only a tiny fraction of the Western Arctic Caribou herd's otherwise pristine range. Also, mine operators and workers have implemented policies to minimize conflicts between traffic and caribou along the road from the mine to the port site (Dau, 2009). In Norway movement patterns and range use by wild reindeer have been disrupted by combinations of highways and railroads, as well as by large hydroelectric developments (Nellemann et al., 2001;

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Nellemann et al., 2003). Impacts of any development tend to be less when they occur on non-critical seasonal range, in areas or at times when caribou are at low density relative to available range, or when similar habitats are available nearby (Griffith et al., 2002).

Interspecies Interactions

The interrelationships of wolves, caribou, and moose populations have been studied extensively in Alaska (Gasaway et al., 1983; Mech et al., 1998; National Research Council, 1997). In large areas of interior Alaska, moose tend to persist for long time periods at low densities, with population size regulated by high rates of predation by wolves and bears (Gasaway et al., 1992). In contrast, caribou are able to periodically escape regulation by predators and at least temporarily achieve high densities (Davis and Valkenburg, 1991; Valkenburg, 2001). Such a pattern is consistent with caribou population dynamics in the Nushagak and Kvichak watersheds. Predation by wolves does not appear to be a major factor in regulating the Mulchatna herd, possibly due to rabies outbreaks that periodically reduce the wolf population (Valkenburg et al., 2003; Woolington, 2009a). Large migratory caribou herds like the Mulchatna may also avoid predation by moving seasonally to areas with few resident predators or by erratic and unpredictable use of seasonal ranges. Wolves in the Nushagak and Kvichak drainages are not known to follow migratory caribou (Woolington, 2009a).

Mortality, Productivity, Survivorship

Mortality- Caribou populations are influenced by the availability and quality of forage plants, predation, weather, climate, disease, and hunting (Valkenburg, 2001). Winter severity, accidents, and insect harassment can also affect caribou numbers (Hinkes et al., 2005). Rapid growth of the Mulchatna herd from 1980 to 1995 indicated that predation pressure was not a limiting factor on the herd at that time. During its continued decline from 1997 to the present, this herd has been strongly limited by nutrition. Poor nutrition has also been associated with high levels of bacterial pneumonia, hoof rot (*Spherophorous necrophorous*) and high parasite loads (Valkenburg et al., 2003; Woolington, 2009a).

Predation by wolves and bears is now limiting calf survival and recruitment in the Northern Alaska Peninsula herd, but lowered productivity due to nutritional stress is also a problem (Butler, 2009a). Calf recruitment in the Nushagak Peninsula Herd has been lower, as the herd declined in recent years, but causes are not well known. Depletion of lichens on winter range may have contributed to poor nutrition (Valkenburg et al., 2003).

Breeding- Rutting occurs during fall migration and on wintering grounds. Females tend to breed at 28 months of age, but age at first breeding can vary from 16 to 41 months, depending on health (Hinkes and Van Daele, 1996). Females in good nutritional condition have a pregnancy rate of 80% or more, but pregnancy rates may drop dramatically when cows are in poor condition, due to severe weather effects on grazing, or in some cases, due to overgrazing of range when caribou are at high densities. Gestation typically takes 225 to 235 days. Calving occurs in late May or early June and females usually have one calf per year (Skoog, 1968). Birth rates in the Mulchatna, Northern Alaska Peninsula, and Nushagak Peninsula herds all dropped after these herds reached peak population levels and then began to decline (Valkenburg et al., 2003).

Human Use/Interaction/Management

Nearly all caribou harvested in the Nushagak and Kvichak watersheds are from the Mulchatna herd. Caribou are an important subsistence food species for people residing in the area served by the Bristol Bay Area Health Corporation (Ballew et al., 2004). In a survey about traditional food consumption conducted in 2002, 88% of respondents from that region reported consumption of caribou meat within the past year (Ballew et al., 2004). Caribou was second only to salmon as a subsistence source of meat for residents of the region. Caribou are also harvested by non-local residents, who fly into the area to hunt. Harvest levels for all hunters are highly dependent on caribou distribution during the fall and winter, as well as weather and snow cover conditions that affect hunter access to caribou (Woolington, 2009a). Harvest is also generally correlated with population size, with historically high harvests occurring when caribou have been most abundant. Reported harvest of Mulchatna herd caribou from 1991 to 1999 ranged from 1,573 to 4,770 (Table 5); although those totals include Mulchatna caribou taken in areas outside the Nushagak and Kvichak drainages (Woolington, 2009a). Estimates of total harvest from the Mulchatna herd during this period were roughly twice as high (3,770 to 9,770)(Valkenburg et al., 2003). However, harvest probably never exceeded 5% of the annual population and did not limit herd growth or range expansion or cause the decline of the population (Woolington, 2009a). As the Mulchatna herd declined in numbers after 1999, reported harvest steadily dropped to a low of 767 in 2007/2008 (Table 5). Lower harvests reflect generally reduced availability of caribou (Woolington, 2009a). Also, long hunting seasons, high bag limits (five caribou), and same-day-airborne hunting that were allowed during the 1990s and early 2000s have since been replaced by more restrictive regulations.

Table 5. Mulchatna caribou herd- estimated population size and harvest.

Regulatory Year	Estimated Herd Size	Reported Harvest
1991-1992	90,000	1,573
1992-1993	115,000	1,602
1993-1994	150,000	2,804
1994-1995	180,000	3,301
1995-1996	190,000	4,449
1996-1997	200,000	2,366
1997-1998	N/A	2,704
1998-1999	N/A	4,770
1999-2000	175,000	4,467
2000-2001	N/A	4,096
2001-2002	N/A	3,830
2002-2003	147,000	2,537
2003-2004	N/A	3,182
2004-2005	85,000	2,236
2005-2006	N/A	2,175
2006-2007	45,000	921
2007-2008	N/A	767

(Woolington, 2009)

Hunting for Nushagak Peninsula Herd caribou is managed under regulations set by the Federal Subsistence Board. From 1995 to 2011, a total of 673 caribou were reported harvested from this herd. Reported harvests were < 12.3% of the population annually during this period (Aderman and Lowe, 2011), but there may have been additional unreported harvest (Valkenburg et al., 2003). Factors other than hunting (e.g., depletion of lichens on winter range) may have been involved in the decline of the Nushagak Peninsula Herd after 1999 (Valkenburg et al., 2003). Nevertheless, it was clear that the herd could no longer support the high levels of harvest seen during the 1990s. Harvest quotas were reduced and the herd is now increasing again.

With the Northern Alaska Peninsula herd now at very low population levels, the herd no longer extends as far north as the Kvichak drainage. Overall harvest of the herd is greatly restricted, and none occurs in the Nushagak and Kvichak watersheds.

WOLF

Introduction

The gray wolf (*Canis lupus*) is the largest wild extant canid (Paquet and Carbyn, 2003). The historic distribution of wolves once covered most of North America, but as the contiguous United States were settled during the past two and one-half centuries, the wolf was widely persecuted due to its tendency to prey on livestock and pets (Mech, 1995). By the 1970s, wolf populations in the contiguous United States were decimated, which led to their protection under the Endangered Species Act. The gray wolf is currently listed as "endangered" in most of the Lower 48 states, except in Minnesota, where it is "threatened," in the northern Rocky Mountains where the species was recently de-listed as "recovered," and for several experimental populations in Wyoming and the southwest United States (USFWS, 2011).

Habitat

Wolves are habitat generalists and their home ranges can encompass a variety of diverse habitats (Mech, 1970; Mladenoff et al., 1995; Paquet and Carbyn, 2003). Historically, gray wolves were distributed throughout the northern hemisphere in every habitat where large ungulates were found (Mech, 1995). Prey abundance and availability strongly influence habitat use by wolves (Paquet and Carbyn, 2003). Male and female wolves do not differ in habitat selection, and the pack maintains their territory throughout the year.

Wolf pups are born, protected, fed, and raised in natal and secondary den sites, a series of rendezvous sites, and surrounding areas (Paquet and Carbyn, 2003). Dens provide shelter and are often located in a hole, rock crevice, hollow log, overturned stump, abandoned beaver lodge, or expanded mammal burrow (Paquet and Carbyn, 2003). Rendezvous sites are areas where pups are left while pack members forage (Theberge, 1969).

Decades ago, it was commonly thought that wolves needed wilderness to survive. More recent studies have shown that wolves do not need wilderness, but they do require adequate prey and a relatively low rate of mortality caused by humans (Mech, 1995; Mladenoff et al., 1999). The presence of roads has a complex impact on habitat selection by wolves. Roads benefit wolves by easing their travel and access to prey, but conversely roads are associated with human contact and increased wolf mortality through either intentional or accidental killing (Houle et al., 2010; Mladenoff et al., 1999). Near the Kenai NWR in Alaska, wolves preferred a gated pipeline road, presumably because it offered an easy travel corridor with little human use (Thurber et al., 1994). In that study, wolf absence from human-settled areas and heavily travelled roads seemed to be caused by wolf behavioral avoidance rather than direct human-caused mortality of wolves in those areas.

Food Habits

<u>*Diet*</u>- Wolves are obligate carnivores whose use of prey depends largely on the availability and vulnerability of ungulates (Weaver, 1994). Dietary habits such as preferred prey species and prey switching tactics vary substantially among wolf packs in different locations, in response to local ecological relationships.

Wolves can be flexible and shift to non-ungulate prey species when ungulate prey are scarce (Forbes and Theberge, 1996) or to take advantage of seasonally abundant, nutritious alternate prey species such as salmon (Darimont et al., 2008). Some wolf packs require dietary supplementation during the summer, in order to meet the high energetic demands of reproduction (Paquet and Carbyn, 2003). Dietary supplementation by alternate prey species is also important for wolf packs in northwestern Alaska that rely on migratory caribou, which move seasonally to calving grounds inaccessible to wolves (Ballard et al., 1997).

Beavers and snowshoe hare are important to the winter diet of wolves in Algonquin Park in Ontario, as are scavenged moose carcasses (Forbes and Theberge, 1992; Forbes and Theberge, 1996). Other animals such as lemmings, voles, muskrat, and a variety of birds (especially waterfowl) and their eggs also supplement the wolf diet (Kuyt et al., 1981), while fish and berries are consumed seasonally, where available (Darimont and Paquet, 2000; Kohira and Rexstad, 1995).

Coastal wolves also consume marine mammal carcasses, mussels, crabs, and even barnacles (Darimont and Paquet, 2000). The Ilnik wolf pack on the Alaska Peninsula was found to preferentially utilize coastal habitat along Bristol Bay, where it was frequently observed consuming marine mammal carcasses that had washed ashore (Watts et al., 2010). In the winter, when Bristol Bay was frozen, the pack was documented using offshore sea ice, and wolves killed sea otters (*Enhydra lutris kenyoni*) near the coastline when the otters were trapped above the sea ice (Watts et al., 2010).

Wolves on the Kenai Peninsula of Alaska were found to rely heavily on moose during the summer (Peterson et al., 1984). Moose comprised an estimated 97% of ingested prey biomass in summer, which was largely scavenged from old kills; only 16% of moose carcasses found with summer wolves were fresh kills. In contrast, 80% of moose consumed during the winter were fresh wolf-kills (Peterson et al., 1984). Kenai Peninsula wolves also ate snowshoe hare and beaver during the summer, and minor quantities of small rodents, birds, vegetation and other prey (Peterson et al., 1984). Scat from wolves in south-central Alaska confirmed reliance on moose; beaver and snowshoe hare were also commonly consumed (Ballard et al., 1987). Wolves in south-central Alaska also eat caribou, muskrat, squirrel, voles, vegetation, and a variety of other dietary items (Ballard et al., 1987).

Salmon as a Food Source[2]- Preying on salmon may have considerable adaptive value for wolves regardless of ungulate density. Foraging theory predicts the avoidance of dangerous ungulate prey in favor of less dangerous alternatives such as salmon (Stephens and Krebs, 1986). Salmon also offers superior nutritive value; in one study pink salmon contained more than four times as much energy per 100 g of meat than raw black-tailed deer (Darimont et al., 2008). Behavioral observations suggest that wolves may have a broad history of seasonal consumption of salmon in areas where the two species co-exist (Darimont et al., 2003).

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[2] Ongoing research in LCNPP and the Alaska Peninsula and Becharof NWRs is providing new information on the relationship of wolves to salmon. The results of this research have not yet been analyzed or published, but preliminary results show that wolves rely on salmon, when available, for a significant portion of their diets. This information is cited as a personal communication in this section.

Wolves have often been observed consuming only the head of salmon instead of the whole fish (Darimont et al., 2003). There are several possible explanations for this behavior. Wolves may be consuming only the most energetically valuable part of the prey item, or they may be targeting specific micronutrients such as omega-3 fatty acids (Gende et al., 2001). Wolves may also be selecting head tissue to minimize their exposure to parasites such as *Neorickettsia helminthoeca*, which can infect salmon and can be fatal to canids (Darimont et al., 2003).

Wolf packs that seasonally utilize salmon can reap benefits during the fall and winter seasons. The consumption of salmon in the fall may improve pup survivorship during weaning (Person, 2001). Winter snow can preserve salmon carcasses buried underneath, enabling use by wolves and other scavengers for the rest of the winter (Carnes 2004). Carnes (2004) compared scat across different packs in the Copper and Bering River deltas, and noted that wolf consumption of salmon increased in winter relative to other seasons; he hypothesized this might be related to the relative lack of seasonal availability of moose in those areas.

Several studies in Alaska have examined the importance of salmon to wolves from various parts of the State. In the Copper and Bering River Deltas, late summer rendezvous sites for wolves were typically located alongside shallow spots in spawning areas or at bends where gravel bars extended out into streams (Carnes 2004). Researchers observed wolves, especially pups at these spots, waiting for spent salmon carcasses to float by (Carnes 2004). In southeast Alaska marine protein composed 18% of the lifetime total diet of Alexander Archipelago wolves; most of the marine contribution was likely salmon, but other marine organisms were probably also consumed (Szepanski et al., 1999). In southwest Alaska's Togiak NWR, wolves have been observed delivering intact salmon carcasses to their pups at rendezvous sites (Walsh, 2011). Similar foraging behaviors have been observed among wolves on the Alaska Peninsula (GMUs 9C and 9E, extending from the Naknek River drainage through Port Moller), where wolves often transport captured salmon to den or rendezvous sites (Watts, personal communication).

Salmon are not solely a food resource for coastal wolves. Some Pacific salmon migrate long distances inland, returning to spawning grounds that may be hundreds of miles from the ocean (Quinn, 2004). A study within DNPP, in Interior Alaska, documented substantial seasonal salmon consumption among wolves who lived more than 1,200 river km from the coast (Adams et al., 2010). Wolves with ranges in areas where salmon were seasonally abundant and ungulates occurred at low densities ate the most salmon; salmon averaged 17% of their total long-term diet (Adams et al., 2010). Preliminary data from LCNPP indicates that wolves use salmon from the time the fish enter streams, through the fall, and then again after late-winter ice out (Mangipane, personal communication).

Dispersal of Marine-Derived Nutrients (MDNs) by Wolves- The influences of salmon on terrestrial systems are largely dependent on predators that remove salmon from streams, consume a portion, and leave the remains behind (Hilderbrand et al., 1999a; Reimchen, 2000). Abandoned salmon carcasses contribute to ecosystem processes, as scavenging, decomposition, and fecal-urinary deposition provide MDNs to terrestrial systems that are typically nitrogen- and phosphorus-limited (Ben-David et al., 1998; Hilderbrand et al., 1999a; Reimchen, 2000; Willson et al., 1998).

Wolf behavior further influences the pattern of distribution of MDNs to terrestrial ecosystems, as wolves often transport caught salmon some distance rather than consuming it in the stream or immediate vicinity. In British Columbia wolves were observed to consume caught salmon on grass next to the river 70% of the time (Darimont et al., 2003). However, in LCNPP, preliminary data indicate that wolves move considerable distances over several days to feed on salmon. In 2009, in LCNPP, an individual wolf was documented travelling up to 64 km from a den site to feed on salmon and carry ingested remains back to feed pups. In 2010 and 2011, the same individual travelled up to 24 km and 40 km to feed on salmon (Mangipane, personal communication). In some locations, wolves consume only the salmon head, leaving the remainder of the carcass behind (Darimont et al., 2003), whereas bears often consume eggs, muscle and other body parts of salmon, especially when salmon density is not high (Gende et al., 2001). In LCNPP wolves have been observed feeding on fish carcasses frozen into lake ice, and the backbones and heads left from human subsistence fishing (Mangipane, personal communication; Spencer, personal communication).

Behavior

Wolf Packs- Gray wolves are territorial and social carnivores that typically live in packs of about six to eight animals but packs may include >20 wolves (Mech and Boitani, 2003). Wolf packs typically consist of a single breeding pair, pups of the year, and their older siblings (Mech and Boitani, 2003). Mating occurs during late January to March and gestation is usually 63 days. In each pack, a single litter of pups is born in a den during late April to May. Nonetheless, multiple litters have been observed within some packs occurring in Alaska (Ballard et al., 1987; Meier et al., 1995). Litter sizes range from one to 12 pups but usually four to six pups are born (Fuller et al., 2003). Dens in coastal temperate rainforests are located within the root wads of living or dead trees (Person and Russell, 2009). In boreal forest or tundra, dens are located in sandy areas or gravel eskers (Ballard and Dau, 1983; McLoughlin et al., 2004). Wolves and their pups occupy dens between late April and early July, and then move to rendezvous sites where sequestered pups are fed by pack members until September or early October when they are sufficiently large to move with the pack (Mech et al., 1998; Packard, 2003; Person and Russell, 2009). Pup mortality during summer is affected strongly by availability of food (Fuller et al., 2003). Wolves usually remain within their natal packs until they reach sexual maturity at 22 to 24 months. At that age, some may disperse from their packs to find mates and establish their own packs. However, researchers reported dispersers ranging in age from 10 months to 5 years (Mech and Boitani, 2003). Abundant prey may induce some wolves to defer dispersal until they are older and thus packs may grow to large size (Fuller et al., 2003; Mech and Boitani, 2003). Dispersing wolves may travel hundreds of kilometers and traverse very difficult terrain before settling (Mech and Boitani, 2003) and they are able to cross large bodies of water. For example, in southeastern Alaska, dispersing wolves were documented swimming 3 to 4 km in open ocean to move between islands (Person and Russell, 2008).

Range- Resident wolf packs occupy extensive territories that they attempt to defend from other wolves. Wolf territories tend to be smaller in summer, when packs remain closer to dens and home sites (Mech, 1977), and are larger in winter, when the pack resumes nomadic travelling as pups mature. In south-central Alaska, the average distance between dens of neighboring packs was 45 km (Ballard et al., 1987).

Territories of wolf packs tend to be much larger in Alaska than in the remainder of the United States, due to the relatively low density of prey in Alaska. Home ranges and pack sizes largely are influenced by availability of prey (Mech and Boitani, 2003). For example, when prey is abundant, home ranges tend to be small and pack sizes large and the opposite is true when prey are scarce. In Alaska, ungulates such as moose, caribou, and Sitka black-tailed deer (Odocoileus hemionus sitkensis) are the most important prey (Gasaway et al., 1992; Kohira and Rexstad, 1997). In general, wolf territory size is inversely related to the density of available prey (Fuller et al., 2003). Average territory sizes of wolf packs from different regions of Alaska were consistently larger in winter than in summer (Table 6) (Adams et al., 2008; Ballard et al., 1997; Ballard et al., 1998; Ballard et al., 1987; Burch et al., 2005; Peterson et al., 1984). Each of these studies of Alaska wolf packs documented territory sizes much larger than those of wolves from north-central Minnesota, where small winter territory size (average 116 km^2) and high wolf density (39/1,000 km^2 in mid-winter) were attributed to an abundant white-tailed deer population (Fuller, 1989). Preliminary analysis of recent data from LCNPP has shown annual ranges from 1,155 km^2 to over 5,000 km^2. One pack in this study had ranges of 2,214 km^2, 2,189 km^2, and 1,834 km^2 from 2009 to 2011 (Mangipane, personal communication).

Table 6. Average territory sizes (km^2) of wolf packs in Alaska*.

Region	Summer	Winter	Annual	Reference
Northwest	621	1,372	1,868	Ballard et al., 1997
Denali National Park	--	--	871	Burch et al., 2005
Central Brooks Range	--	--	358–2,315[a]	Adams et al., 2008
Kenai Peninsula	--	--	466-864[b]	Peterson et al., 1984
South-central	--	--	1,644	Ballard et al., 1987

a - Range of territory sizes estimated for wolf packs over the four-yr study period
b - Range of average annual territory sizes during study period
-- not determined
* This table does not include data from an ongoing study in LCNPP.

Dispersal (Emigration)- Several studies in Alaska have documented emigration as a vital factor influencing the population dynamics of wolves (Adams et al., 2008; Ballard et al., 1997; Ballard et al., 1987; Peterson et al., 1984). Individuals may leave a pack and strike out on their own in response to low prey densities (Messier, 1985). High rates of infectious disease (Ballard et al., 1997), social stress within the pack, or a lack of opportunity to achieve the high social status needed to successfully breed (Peterson et al., 1984) may also cause wolves to disperse to new territories.

Dispersal is a key mechanism that wolves use to colonize new habitats that become available. Dispersing wolves experience a high rate of mortality, but when successful, they are able to establish a new pack (Peterson et al., 1984) or join an existing pack (Mangipane, personal communication). Successful colonization of new territory requires both a vacancy of suitable habitat and bonding with a mate (Rothman and Mech, 1979).

Seasonal Movements- Wolves in south-central Alaska do not follow migratory movements of moose or caribou outside their pack areas, but do follow elevation movements of moose within their pack areas (Ballard et al., 1987). In a study in northwest Alaska, wolf packs usually did not follow migratory caribou from the Western Arctic herd, but rather, switched to moose for prey during the winter and maintained year-round resident territories (Ballard et al., 1997). However, in years when moose densities were low, up to 17% of radio-collared wolf packs in northwest Alaska followed migratory caribou and then returned to their original territory for denning (Ballard et al., 1997).

In Bristol Bay, there is no evidence that wolf packs follow the Mulchatna caribou herd, although wolves are occasionally seen with the herd as it moves throughout the region (Woolington, 2009b). However, recent information in LCNPP shows that wolves (in most cases, lone yearling wolves) were following caribou herds for all or a portion of the year (Mangipane, personal communication). Packs are more likely to have established territories and take advantage of caribou when they move through those territories.

Daily distances traveled within a pack's territory range from a few kilometers up to 200 km (Mech, 1970). On Ellesmere Island, Northwest Territories, mean travel speed of wolves during summer, on barren ground, was 8.7 km/hr for regular travel and 10.0 km/hr when returning to a den (Mech, 1994). In south-central Alaska, a wolf pack followed for 15 days in the spring moved an average of 24 km per day (Burkholder, 1959). In LCNPP, all packs and age classes of wolves have been documented travelling up to 34 km in 15 hours (Mangipane, personal communication).

Wolves in general are good swimmers; coastal wolves are particularly adept at swimming and are able to swim distances as far as 13 km between islands (Darimont and Paquet, 2002). However, wolves may be unwilling to swim in pursuit of large ungulates. On the Kenai Peninsula, wolves ceased pursuit of moose that entered ponds or lakes and swam away from shore (Peterson et al., 1984). However, as soon as waterbodies freeze, wolves travel across them freely (Spencer, personal communication).

Interspecies Interactions; Response to Change in Salmon Populations/ Distribution

In coastal regions and along major river systems salmon are important seasonal prey for wolves (Adams et al., 2010; Kohira and Rexstad, 1997). Indeed, in some coastal areas, salmon may seasonally decouple the dependence of wolves on ungulate prey (Darimont et al., 2008). Salmon is a particularly important food for Alaskan wolf packs in some areas and changes in salmon abundance may have effects on the alternate prey species of these wolves. In DNPP, salmon were found to be a particularly important food item for wolves in areas with low ungulate density but high salmon abundance (Adams et al., 2010). The availability of salmon had a strong impact on the numerical abundance of wolves in the northwestern flats area of DNPP; wolves were only 17% less abundant in that area compared to the rest of the study area, even as ungulate densities were 78% lower. The higher wolf population density facilitated by the availability of salmon was thought to result in increased overall predation pressure on ungulates in that system (Adams et al., 2010). Moose were the predominant ungulate in the northwestern flats, occurred at densities

approaching the lowest in North America (Gasaway et al., 1992), and appeared to be limited by predation rather than nutritional constraint (Adams et al., 2010).

Some wolves in Alaska eat salmon carcasses throughout the winter, as cold winter temperatures and snowfall effectively preserve this food resource. In one study of wolf scat, salmon consumption was observed to increase in the winter relative to other seasons (Carnes, 2004). A shortage of available salmon might result in a reduced winter food supply for such wolves, which could lead to either increased predation pressure on alternate prey species or reduced wolf survival if alternate foods were not available.

In Alaska, ungulates such as moose, caribou, and Sitka black-tailed deer are the most important prey (Gasaway et al., 1992; Kohira and Rexstad, 1997). Under some circumstances, predation by wolves may limit or regulate ungulate populations, sometimes suppressing their numbers at very low densities (top-down forcing) (Gasaway et al., 1992). In other cases, ungulate populations are influenced mostly by carrying capacity of the range regardless of wolf predation (bottom-up effects) (Ballard et al., 2001). Nonetheless, the relative effects of top-down and bottom-up factors can shift over time depending on habitat changes, weather conditions, and anthropomorphic disturbances (Bowyer et al., 2005).

The interrelationships of wolves, caribou and moose populations have been characterized in several ecosystems. Alterations in moose densities can have a major influence on caribou populations, through their effect on wolf predation rates. In southeastern British Columbia, wolf population numbers can be suppressed due to a lack of available food in winter, when moose numbers are low, particularly when caribou over-winter in areas inaccessible to wolves (Seip, 1992). Elevated moose densities may cause a concomitant rise in wolf numbers. If moose numbers later decline, wolves in the area will turn to caribou as an alternative food source, potentially causing a profound effect on the caribou population. Industrial development can exacerbate this effect by increasing wolves' access to caribou, via the creation of new linear corridors, such as roads and pipelines (James et al., 2004). These interrelationships may not be applicable to the southwest Alaska ecosystem, which has barren-land caribou herds, in contrast to the low-density woodland caribou herds from the Canadian studies. In LCNPP, when the Mulchatna caribou herd was at high numbers, wolves fed on caribou and moose numbers were high. When the herd size declined, wolves fed more on moose and moose numbers declined by 50 percent (Mangipane, personal communication).

Wolves are coursing predators that actively pursue prey rather than passively ambushing them (Mech, 1970; Mech et al., 1998). Consequently, in much of Alaska, they typically select open or sparsely forested habitats that enable detection and pursuit of prey. Deep snow that hinders movement of ungulate prey or restricts them to small, forested patches often facilitates predation by wolves (Mech and Peterson, 2003). For large ungulate prey such as moose, wolves often focus predation on calves, which tend to be the most vulnerable. In interior Alaska, wolves are most effective hunting in flat or rolling terrain covered with sparse boreal forest or tundra. In coastal rainforests, prey tend to be most vulnerable to predation by wolves in open muskeg heaths at low elevations (Farmer et al., 2006).

Mortality, Productivity, and Survivorship

Annual mortality in unexploited wolf populations in Alaska and Yukon ranges from 16 to 27% and is linked strongly with abundance of prey (Fuller et al., 2003). Mortality results from accidents, disease, and intra- and inter-pack strife. Where wolves are hunted and trapped, human exploitation often is the overwhelming source of mortality (Fuller et al., 2003; Person and Russell, 2008). In a heavily exploited population in south-central Alaska average annual mortality was 45% of which most (36%) was human caused (Ballard et al., 1987). Human-caused mortality can be compensatory with respect to other sources of natural mortality (Fuller et al., 2003). Resident pack members usually have higher survival than nonresident dispersing wolves because dispersers may be traveling through unfamiliar or unsuitable terrain, and are subject to attacks by resident wolves (Fuller et al., 2003).

Wolves can live for up to 13 years in the wild (Mech, 1988), typically dying as a result of starvation, accidents (Mech, 1977), intra-specific fights (Ballard et al., 1987), disease (Ballard et al., 1997; Woolington, 2009b), or human-related causes (Paquet and Carbyn, 2003; Woolington, 2009b). Starvation and disease are often co-occurring, but the nature of that relationship has not been fully established (Paquet and Carbyn, 2003). When wolves attempt to take down large prey, such as moose or caribou, they risk injury or death (Mech, 1970; Paquet and Carbyn, 2003). Human-related causes of wolf mortality include legal hunting for sport, subsistence or predation control (Ballard et al., 1997; Ballard et al., 1987; Woolington, 2009b).

Wolves have prolific reproductive potential (Ballard et al., 1987; Boertje and Stephenson, 1992), and pups generally experience high survival rates through their first autumn (Adams et al., 2008; Ballard et al., 1987). These pulsed increases in pack size each year must be compensated for by a combination of mortality and emigration, if the population size is to remain roughly constant over time (Adams et al., 2008). The relative contribution of emigration, natural mortality, and human-caused mortality in wolf packs has varied substantially in different parts of Alaska.

In the central Brooks Range in northern Alaska, during the period 1987 to 1991, the resident wolf population increased by 5% per year while experiencing a 12% annual harvest rate (Adams et al., 2008). Harvest and natural causes were each responsible for half the annual mortality in radio-collared wolves. Causes of natural deaths in those wolves, when distinguishable, were wolves killing other wolves (n=6), avalanche (n=1), and old age (n=1) (Adams et al., 2008). Pups constituted about half the wolf population each autumn, and young wolves emigrated from the study area at high rates as yearlings (47%) and two-year-olds (27%).

In northwest Alaska, during the period 1987 to 1992, the annual survival rate averaged 55.2% for radio-collared wolves (Ballard et al., 1997). Hunting was responsible for 69% of known mortalities. Rabies was also a significant cause of death in this population (21% of mortalities) during the period 1989 to 1991. Twenty-one wolves (25%) dispersed from their original territory during the study, with the highest rates of dispersal occurring during the rabies outbreak.

In south-central Alaska, in GMU 13 (the Nelchina and upper Susitna basins), wolf population levels were highest at the beginning of one study period (1975) and declined each year through the end of the study (1982), due to aircraft-assisted ground shooting and state-managed wolf control (Ballard et al., 1987). Litter sizes in this wolf population ranged from two to nine pups,

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with an average of six pups. Natural mortality accounted for only 20% of total wolf mortality in that study. That wolf population could sustain a mortality rate of 50% from all sources before experiencing a population decline. Human harvests in excess of 40% of autumn wolf numbers caused population declines. Wolf control practices were effective at reducing wolf numbers, but when wolf control ceased the wolf population rebounded quickly.

Wolves re-established on the Kenai Peninsula by natural immigration in the 1960s, after being absent since the early 1900s. That wolf population was studied during the period 1976 to 1981, and population changes were documented (Peterson et al., 1984). Wolf density in the winter of 1976/1977 was 11 wolves/1,000 km^2; density increased to 16 in 1978/1979, dropped to 11 to 12 in 1980/1981, and increased back to 18 to 19 in 1981/1982. Annual survival rate for radio-collared wolves declined during each year of the study, from 100% in 1976/1977 to 44% in 1980/1981. Harvest was responsible for the majority of mortality. Reported harvest averaged 30% annually, and annual mortality of radio-collared wolves was 32%. Dispersal was found to play a key role in wolf population dynamics during this study. Dispersing wolves were highly vulnerable to harvest (the annual survival rate for dispersing adults was only 38%, compared to 73% for resident adults), but those dispersers who survived to reproduce were critical to the maintenance of population densities in spite of increased mortality rates (Peterson et al., 1984).

In LCNPP 17 wolves were radio collared in a three-year period (2009 to 2011). Of the 17 wolves collared, eight died during that time. Three were harvested, two died in intra-specific fights, one drowned, and two died from unknown causes. Annual survival for all age classes for each year of the study was 75%, 63%, and 75%. Of five dispersing wolves in LCNPP, survival was estimated at 60%, but this is likely a high estimate (Mangipane, personal communication).

Population Estimates

There are between 7,000 and 11,000 gray wolves in Alaska. The highest densities occur on the islands associated with the southeastern panhandle where deer (are the principle prey and the lowest densities occur in mountainous areas where prey consists mostly of Dall sheep or mountain goats (Fuller et al., 2003; Person et al., 1996). Two genetically distinct wolf populations are recognized within Alaska, those occupying the coastal zone of southeastern Alaska and those inhabiting the rest of the state (Weckworth et al., 2005). During 2000 to 2009, 1,200 to 1,600 wolves, about 14 to 16% of the estimated population, were reported harvested annually in Alaska. It is estimated that wolf populations can usually sustain 30 to 40% total annual mortality (Fuller et al., 2003).

Wolf population numbers have not been well studied in the Nushagak and Kvichak watersheds. Better regional wolf population estimates, gathered using scientifically rigorous methods, are needed to improve understanding of wolf populations in the study area. Wolf populations are highly dynamic, so population estimates must be conducted on a relatively frequent basis. Additionally, wolf population numbers in this area are difficult to obtain due to vegetation and inconsistent snow conditions. Dense vegetation and sparse or inconsistent snow make sighting of wolves from the air challenging.

No population estimation surveys for wolves have been conducted in the Nushagak watershed (GMUs 17B and 17C; Figure 3) (Woolington, 2009b). ADF&G impressions of wolf population

status in GMU 17 (the Nushagak and Togiak watersheds, west to Cape Newenham) are based on observations of wolves and tracks, reports from the public, bounty records from 1962 through 1971, mandatory sealing records from 1972 to present, and an annual trapper questionnaire program initiated in 1988 (Woolington, 2009b). Based on these data, ADF&G biologists conclude that wolf density in GMU 17 peaked from 1974 to 1977 and then declined sharply by 1980. Wolf densities seemed to increase again until 1989, when a rabies outbreak affected canid populations in GMU 17. Wolf populations began to increase again in 1992, and wolves are now thought to be "abundant" throughout GMU 17 (Woolington, 2009b). Woolington (2009) provided current wolf population estimates for GMU 17, but these were considered too speculative to rely on for this assessment and are not repeated here.

The Kvichak watershed, the other large drainage in the study area, is located in GMU 9, which extends from LCNPP to False Pass. Wolf population estimates for the region are available, but they should be used with caution for several reasons. ADF&G has grouped GMUs 9 and 10 (the Aleutian Islands) for statistical purposes, so those wolf population estimates include lands outside the study area. Also, wolf population dynamics have been studied only lightly in the region, and only limited descriptions of methods and results are available (Butler, 2009b). Methods consisted of monitoring ten wolf packs using radio-collar tracking, monitoring trends through observations during other fieldwork, reviewing reports from hunters and guides, and collecting responses to annual trapper questionnaires. Using these data, ADF&G estimated a total population of 350 to 550 wolves in GMUs 9 and 10 (Butler, 2009b). Biologists concluded that wolf densities in GMU 9 and 10 are low to moderate, but wolf numbers in GMU 9 appear to have increased since the 1990s, despite a decline in caribou populations. Possible explanations hypothesized for this increase in wolves included an abundance of alternate prey such as marine mammal carcasses, salmon or snowshoe hares, a population rebound following a high period of mortality from a rabies outbreak, or wolf immigration from surrounding areas (Butler, 2009b). Data are not available to directly evaluate these hypotheses. Estimated wolf densities in GMU 9E (the Alaska Peninsula south to Port Moller) and the southwestern portion of GMU 9C (the Naknek watershed outside Katmai NPP) are 6 to 7 wolves per 1000 km^2 (Watts, personal communication).

Human Use/Interaction/Management

Reporting of wolf harvest in Alaska is mandatory, but reporting compliance is suspected to be weak in some areas (Ballard et al., 1997). The degree of reporting compliance within the Nushagak and Kvichak watersheds is unknown. The reported wolf harvest in GMUs 9, 10 and 17 for the period 2003 to 2008 are summarized in Table 7.

Table 7. Total wolf harvests in GMUs 9, 10 and 17 reported to Alaska Department of Fish and Game.

Year	GMU 9 and 10[a]	GMU 17[b]
2003-04	119	141
2004-05	64	60
2005-06	120	62
2006-07	85	79
2007-08	110	73

a= Butler 2009; b=Woolington 2009

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Alaska harvests of wolves vary widely due to fur prices, hunter access to wolf habitat, predator control policies and practices, and population changes in response to prey populations. Hunter access is influenced by winter travel conditions (Woolington, 2009b), including snow depth and fuel prices. Wolves in the Bristol Bay area are typically hunted and trapped by local residents, but are also harvested opportunistically by non-local hunters.

Trappers from southwest Alaska indicated that wolf was the fourth most important species they targeted (as defined by the trappers themselves), behind otter, beaver and fox (in that order) (ADF&G, 2010). State trapping regulations do not distinguish between different types of use, such as "subsistence," "recreational," or "commercial" (ADF&G, 2011b). Most rural Alaska communities are supported by a mixed subsistence-cash economy (Wolfe, 1991). Trapping is one of many traditional subsistence activities that can provide a modest income for participants. Some harvested furs are sold to dealers, but others are used locally. Furs are often made into hand-crafted items, which are more valuable than the raw pelts (Wolfe, 1991). Items commonly crafted with furs include mitts, coats, boots, fur ruffs, and slippers. In some rural areas, households use most of their harvested wolf pelts locally for ruffs, hats, and lining for winter gear, because imported materials are considered inferior (Wolfe, 1991).

WATERFOWL

Introduction

The purpose of this report is to provide a characterization of waterfowl resources (Anatidae) in the Nushagak and Kvichak watersheds. The waterfowl family includes swans, geese, and ducks (dabbling, diving, and sea). This overview is not a comprehensive account of the status, ecology, and life history of all species of waterfowl that regularly occur in the Bristol Bay region. Instead, this section briefly summarizes the prominent species, general habitat associations and their seasonal occurrence by subregion; highlights some primary ecological relationships between waterfowl and sources of nutrients, particularly salmon, that support habitats and food resources; and describes human values and uses of waterfowl from Bristol Bay. Waterfowl data and other biological information are from currently available sources.

Waterfowl information in this report has been organized by geographic subregions (Estuaries and Inner Bay, Lowlands and Inland Tundra/Taiga) because of substantially different species composition, seasonal use patterns, ecological settings, and extent of available biological information. To a large extent, information in this report is constrained to the Nushagak and Kvichak watersheds, a subset of the greater Bristol Bay region that has been interpreted as widely as the area from Cape Pierce to the end of the Alaska Peninsula.

Regional Overview-

The Bristol Bay region hosts 34 regularly occurring species of waterfowl (Appendix 2). The diverse wetlands and other aquatic habitats of the region include boreal forest and taiga lakes and ponds inland near Lake Clark, river basin wetlands and lakes along the Mulchatna, Nushagak and Kvichak valleys, tundra ponds and lakes of the lowlands, and coastal tide flats and estuaries. The diversity and extensiveness of these habitats provide habitat for many species of waterfowl as breeding birds, migrants during the summer molt, fall and spring migrants, and wintering birds.

Geographically, the Bristol Bay region is positioned as a major northern spring staging area for waterfowl destined to breed in western and northern Alaska, Russia, and Arctic Canada. At the southern extent of Bering Sea ice, the rich estuaries of Bristol Bay provide food and resting areas for migrants that are advancing north in spring (King, 1982). Spring aggregations include swans, geese and ducks arriving from Mexico and the western U.S.; sea ducks from the Pacific coast of North America (Baja Mexico, British Columbia, southeast and Gulf Coast of Alaska); and emperor geese (*Chen canagica*) and sea ducks from the Aleutian Islands.

During summer, the estuaries of Bristol Bay and Kuskokwim Bay to the north serve as traditional molting areas for large numbers of scoters that gather from the Bering Sea and western Arctic regions. These shallows provide food-rich and secure habitats at a time when these birds are nutritionally stressed and flightless. Molting occurs from July through September, varying among subadults and adults, males and females.

Bristol Bay is an important fall staging area for waterfowl migrating south from northern and local breeding areas. Fall migration tends to be faster and more direct to staging areas than spring migration. From mid-August through early October, ducks, Canada (*Branta canadensis*) and

greater white-fronted (*Anser albifrons*) geese move overland through the passes of the Alaska Range to Cook Inlet coastal marshes (Redoubt Bay, Trading Bay, Susitna Flats, and Palmer Hay Flats). Large numbers of ducks and geese orient to the rich lagoons and coastal tundra on the north side of the Alaska Peninsula west to Izembek Lagoon. Canada, cackling (*Branta hutchinsii*) and white-fronted geese; brant (*Branta bernicla*); and most dabbling ducks depart by early November, either eastward along Alaska's south coast or directly across the Gulf of Alaska to points between British Columbia and Mexico. Most dabbling and diving ducks from western Alaska orient to wintering areas in the Pacific Flyway west of the Rocky Mountains, but some greater scaup (*Aythya marila*) and other ducks cross the continent to the Gulf of Mexico and Atlantic Coast (King, 1973; King and Lensink, 1971). Some sea ducks, an increasing number of Pacific brant (Ward et al., 2009), and even a small population of tundra swans (*Cygnus columbianus*) winter along the Alaska Peninsula, while others and emperor geese move into the Aleutian Islands.

History of Waterfowl Surveys-
Much of the quantitative data on waterfowl numbers and distribution in the greater Bristol Bay region are derived from surveys conducted over different areas. In many respects, the distributions and habitat use patterns of waterfowl in the Nushagak and Kvichak watersheds intergrade with habitats west of the Nushagak Peninsula and down the Alaska Peninsula to Izembek Lagoon. Information summarized in this report focuses, as much as possible, on the inner bay, lowlands, and inland subregions of the Nushagak and Kvichak watersheds.

Osgood (1904) provides a broad and detailed description of habitats and wildlife of the Bristol Bay region from his 1902 reconnaissance survey, mostly by canoe, starting from Cook Inlet and travelling to Iliamna Lake and Lake Clark, then up the Chulitna River and down the Koktuli, Mulchatna, and Nushagak Rivers to Bristol Bay. His trip continued by schooner to Egegik, over the Alaska Peninsula at Becharof Lake, and then by rowboat to Cold Bay. Hurley (1931; 1932) records bird observations in the Bristol Bay region. Murie (1959) summarized the environment, habitats and wildlife of the Aleutian Islands and Alaska Peninsula, with some coverage of Kvichak and Nushagak Bays, from his 1936-37 boat-based expedition. Both Osgood and Murie provide species accounts of waterfowl, reviewing records of earlier observers. Gabrielson (1944) compiled general records of birds on his extensive trip in summer 1940, including travel up the Kvichak River, across Iliamna Lake and portage to Cook Inlet. Hine (1919) and Cahalane (1944) described birds of the nearby Katmai region. Gabrielson and Lincoln (1959) provided the most thorough compilation of bird records of their day in *The Birds of Alaska*, including information on migration patterns, ecological zones and detailed species accounts. Gill et al. (1981) describe the waterfowl and other birds of the north-central Alaska Peninsula.

Quantitative surveys of Bristol Bay waterfowl were established in the 1950s to monitor ducks and geese on prime lowland nesting habitats as part of the annual North American breeding population survey (Hodges et al., 1996). Interest in oil and gas exploration and other resource development stimulated more extensive surveys of waterfowl in coastal areas (Bartonek and Gibson, 1972; King and McKnight, 1969). The Coastal Zone Management Act of 1972 provided funding to states to synthesize information and establish cooperative wildlife resource inventories in coastal areas (Timm, 1977). In 1974, the Outer Continental Shelf Environmental Assessment Program (OCSEAP) stimulated many surveys and research projects related to

waterfowl in the Gulf of Alaska, Bering Sea, and Beaufort Sea. This program greatly expanded the amount of information on waterfowl and other birds in Bristol Bay (Arneson, 1980). Information on waterfowl and other wildlife resources in the region have been reviewed broadly by Timm (1977); USFWS (1976); and USFWS (1983).

The longest-term and most consistent waterfowl surveys in the Bristol Bay region are part of the Alaska-Yukon Waterfowl Breeding Population Survey (AYWBPS), flown annually by USFWS since 1957 as part of a North American duck survey program (Mallek and Groves, 2010). This survey was designed to index breeding dabbling ducks during the early egg-laying period (late May) to provide annual status data and long term trends. Bristol Bay (Stratum 8 in this statewide survey) is composed of 11 transects in 23 segments, sampling an area of 25,641 km^2 (9,900 mi^2) usually flown in late May.

From 1989 through 1997, USFWS conducted a series of experimental expanded surveys of major tundra waterfowl areas to assess means of providing more reliable annual estimates of abundance (Conant et al., 2007). The expanded waterfowl surveys flown by Platte and Butler (1995) over the Bristol Bay region in 1993 and 1994 covered a much broader area (49,890 km^2) than the traditional AYWBPS, extending west to Togiak Bay and Togiak River drainage, covering more a northerly band from Wood-Tikchik Lakes eastward to Port Alsworth, and southwest on the Alaska Peninsula to include Port Heiden and the Seal Islands. The data from this experimental survey reflect a much wider range of habitats and duck densities than the traditional AYWBPS survey (Conant et al., 2007).

Coastline and estuarine waterfowl surveys of Bristol Bay, focusing on emperor geese, have been conducted annually in spring (1981-2011) (Dau and Mallek, 2011) and fall (1980-2011) (Mallek and Dau, 2011). Steller's eider are the focus of Bristol Bay surveys conducted since 1992 (Larned and Bollinger, 2011).

Waterfowl Resources and Seasonal Occurrence

Estuaries and Inner Bristol Bay-

Bristol Bay estuaries and nearshore waters are important to waterfowl year round, during spring and fall migration, summer molting, and as winter range for some species. King and McKnight (1969) made a first attempt to estimate the number of birds in Bristol Bay during October, flying transects from the high tide line offshore to 12 miles (19.3 km). Their survey covered over 20,700 km^2 of coast from Cape Constantine south and west to Unimak Island, and included lines in outer Kvichak and Nushagak Bays.

During the early 1970s, Bristol Bay became a focal area of the OCSEAP studies, including offshore transect surveys of birds from Kvichak Bay south along the Alaska Peninsula (Bartonek and Gibson, 1972; USFWS, 1976). Most of the survey coverage was over the outer bay beyond the BBWA area, but it provides insights to the seasonal use of Bristol Bay nearshore waters.

Additional coastal bird surveys were flown for OCSEAP between October 1975 and August 1978 (Arneson, 1980). These 33 surveys from the Gulf of Alaska through the Aleutian Islands were designed to assess seasonal bird densities and distributions in littoral/nearshore waters, describe coastal habitats, and document migration. The North-Bristol Bay region was surveyed

in spring (May) by fixed-wing aircraft, helicopter, and boats. Sections 1-6 of the study area covered the coast of Kvichak Bay to Cape Constantine within the BBWA study area.

Habitats- The estuaries and nearshore waters of Bristol Bay provide diverse aquatic habitats for waterfowl and other waterbirds (Michel et al., 1982; Selkregg, 1976). Arneson (1980) classified over 30 types of coastal habitats, ranging from intertidal flats and salt marshes to open waters, to document seasonal usage by birds. He found about 80% of waterbirds on protected delta habitats and exposed inshore waters. Dabbling ducks and geese preferred mudflats and delta habitats; diving ducks and sea ducks were found mostly in exposed inshore and bay waters. A large proportion of Nushagak and Kvichak Bays has water depths of < 10 m (Schamber et al., 2010), which provides very accessible benthic habitats for diving and sea ducks that feed largely on invertebrates.

Geese- Most of the Pacific (black) brant population and the world population of emperor geese migrate through the greater Bristol Bay and Alaska Peninsula regions during spring and fall. Pacific brant breed mostly on the Y-K Delta and also along the Arctic Coasts of Alaska, northeast Russia, and Canada (Pacific Flyway Council, 2002; Reed et al., 1998). During April, Bristol Bay and the Alaska Peninsula serve as staging areas for birds assessing snowmelt and Bering Sea ice conditions. Chagvan and Nanvak Bays near Cape Newenham hold about 50,000 brant during spring, but only small numbers of brant use Nushagak or Kvichak Bays. From late August through mid-September, most brant leave breeding areas and move south along western Alaska directly to the Alaska Peninsula and eventually to Izembek Lagoon where the entire population stages until early November. Most brant depart the Peninsula *en masse* across the Pacific to wintering grounds from British Columbia to California, but most settle in the large bays of Baja Mexico (Dau, 1992; Pacific Flyway Council, 2002). Since the mid-1970s, milder conditions have allowed up to one-third of Pacific brant to winter along the western end of the Alaska Peninsula (Ward et al., 2009).

Emperor geese breed almost entirely on the coastal zone of the Y-K Delta, with a few in Russia (Pacific Flyway Council, 2006; Petersen et al., 1994). They winter from the outer Alaska Peninsula westward into the Aleutian Islands. Like brant, emperor geese migrate in spring and fall through the greater Bristol Bay area and eastern Bering Sea coast. They stage and migrate mainly through bays to the west of the Nushagak Peninsula, but a few emperor geese occur in inner Bristol Bay. During fall large numbers of emperor geese cross Bristol Bay to the large lagoons on the north Alaska Peninsula, particularly the Seal Islands, Nelson Lagoon, and Izembek Lagoon (Petersen et al., 1994).

Ducks- The nearshore waters of Bristol Bay host a large variety of ducks, including most of the common dabbling and diving duck species that use an array of habitats from intertidal marshes to offshore waters. During spring surveys in 1976-77, diving duck densities were 10-100/km^2 along the north side of Kvichak Bay and around Nushagak Bay (Arneson, 1980). Data from Kvichak Bay indicated 259 birds/km^2, mostly shorebirds, dabbling ducks (81/km^2), and diving ducks on tide flats. In south and east Nushagak Bay, high densities (171/km^2) of scaup (*Aythya spp.*) were concentrated along Flounder Flats, mixed with flocks of black scoters (*Melanitta americana*).

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Deeper more open waters are used by diving ducks and sea ducks. Relatively high densities of sea ducks (26/km^2) were recorded during surveys on the east side of the Nushagak Peninsula (Arneson, 1980), composed of 10% long-tailed ducks (*Clangula hyemalis*) and 12% harlequin ducks (*Histrionicus histrionicus*). The majority of ducks in exposed waters and areas out to > 10 m deep were greater scaup, scoters, and eiders (see below). During spring and fall, smaller numbers of long-tailed ducks, harlequin ducks, and goldeneyes (*Bucephala* spp.) occur in the inner Bay. Up to 48,000 long-tailed ducks have been recorded in greater Bristol Bay during April (Larned and Bollinger, 2011) on their way inland or northward for breeding; few long-tails occur during fall (Mallek and Dau, 2011). Harlequin ducks use the bay before and after breeding inland and on their way west to winter in the Aleutian Islands. Mallek and Dau (2011) counted 3,300 harlequins along the Bristol Bay and Alaska Peninsula coast during spring 2010 (peak count 6,114 in 1992) (USFWS, 1976).

Scoters- Bristol Bay, especially Kvichak Bay, is an important staging and molting area for black, surf (*Melanitta perspicillata*), and white-winged (*M. fusca*) scoters spring through fall. Early surveys often did not accurately record scoters by species, but over the past ten years, focused surveys have produced species estimates, especially for black scoters.

Spring OCSEAP surveys along more pelagic transects tallied over 253,000 scoters in May 1972 and 216,000 scoters in April 1973 (USFWS, 1976). Arneson (1980) estimated that black scoters comprised 97% of all scoters counted during spring surveys in 1976 and 1977. More recent spring estimates also have documented large number of scoters in the inner bay, including up to 45,000 black scoters (Larned, 2008).

Scoters gather in Bristol Bay during the wing molt from July through September. OCSEAP surveys counted 180,000 in July 1973 (Dau, personal communication; USFWS, 1976). A high proportion of 77 satellite-marked black scoters from several wintering areas gathered in northeast Bristol Bay where they spent an average of 15-20 days from June through September (Schamber et al., 2010).

Though King and McKnight (1969) did not provide bird distribution data, they documented about 181,000 scoters during October staging, including approximately 140,000 black scoters. On the more pelagic OCSEAP surveys, over 285,000 scoters were estimated in the outer bay during October 1974 (USFWS, 1976). Larned and Tiplady (1998) found about 20,000 black scoters in the bay during late September. Few scoters are thought to winter in upper Bristol Bay (Bellrose, 1980; Schamber et al., 2010); most probably disperse westward along the Alaska Peninsula.

Satellite telemetry indicates that black scoters from widely separate wintering areas (British Columbia, Kodiak, and Dutch Harbor) all used Bristol Bay from spring through fall (Bowman et al., 2007). Analysis of cumulative satellite locations throughout the year indicates that black scoters mostly use specific areas of shallow (< 3 m) waters along the north side of Kvichak Bay, western Nushagak Bay, and Egegik Bay to the south (Schamber et al., 2010).

King Eiders- King eiders (*Somateria spectabilis*) in North America breed across the Alaska North Slope and Arctic Canada, but inner Bristol Bay waters are important to king eiders as both

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a wintering area and as a major spring staging area (Suydam, 2000). Spring, OCSEAP surveys estimated that about 280,000 king eiders were in outer Bristol Bay in May 1972, and over 1.8 million were found in April 1973 (USFWS, 1976). Arneson (1980) estimated eider composition was about 45% king, 36% common (*S. mollissima*), and 19% Steller's (*Polysticta stelleri*) during spring coastal surveys in 1976 and 1977.

In the late 1990s, king eiders marked with satellite tags guided aerial surveys to document staging and molting areas (Larned and Tiplady, 1998). During April surveys for Steller's eiders, Larned (2008) estimated over 570,000 king eiders in Kvichak Bay in 2008; an average of 194,000 king eiders were estimated from these surveys from 2000 to 2009 (Larned and Bollinger, 2011).

Bristol Bay has been documented as one of a few important molt areas for king eiders; other areas include the northeast Russian coast and St. Lawrence Island (Phillips et al., 2006). Based on satellite tracking, Bristol Bay molters arrive from Alaska's North Slope (Phillips et al., 2006) and Arctic Canada (Dickson et al., 2001). Molt periods vary by sex and age of birds, but extend from August to October.

During fall, smaller numbers of king eiders have been recorded in the bay; as many as 20,000 were estimated in late September (Larned and Tiplady, 1998). Southwestern Alaska, especially inner Bristol Bay, is considered one of three main wintering areas of king eiders breeding in western North America, though these birds may move considerably within the region between October and April (Oppel et al., 2008).

Schamber et al. (2010) assessed the distribution of king eiders in Bristol Bay from year-round locations of satellite-marked birds. Across seasons, king eiders used most of the inner bay between the Nushagak Peninsula and Egegik Bay (averaging 10.6 km offshore), including areas with water depths of > 20 m, but they particularly frequented defined areas off Etolin Point, Half Moon Bay, and Egegik Bay where water depths were < 10 m.

Steller's Eiders- Bristol Bay coastal waters host Steller's eiders mostly in spring and fall, but they are not thought to breed in the region. The historical breeding range of the species in Alaska extends from the Y-K Delta into northwest Alaska and the western North Slope (Fredrickson, 2001). Along with a large number of Steller's eiders that breed west to the central Siberian coast, the Alaska birds are part of a Pacific (Russia-Alaska) population that probably numbers between 130,000 (Hodges and Eldridge, 2001; USFWS, 1999) and 150,000 (Fredrickson, 2001). Though historical data are not quantified, the number of Steller's eiders breeding in Alaska declined sometime between the 1940s and 1960s, especially on the Y-K Delta (Kertell, 1991). Based on estimates that there were perhaps fewer than 3,000 birds breeding over a substantially reduced range in Alaska during the 1990s, the USFWS listed the Alaska-breeding component of the population as threatened under the Endangered Species Act in 1997 (USFWS, 2002).

The primary wintering grounds for the Pacific population extends from the central Alaska Peninsula westward into the Aleutian Islands (Fredrickson, 2001). Thus, most birds transit Bristol Bay in spring and fall. Surveys have been conducted to assess the Pacific population during spring migration (April-early May) since 1992, including survey sections between Cape

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Constantine and the Naknek River (Larned and Bollinger, 2011). In general, spring staging Steller's eiders were concentrated along the Alaska Peninsula south of Egegik and west of the Nushagak Peninsula; very few birds used inner Bristol Bay. Coastal emperor goose surveys flown in late April show similar minimal occurrence of Steller's eiders in Nushagak and Kvichak Bays (Dau, personal communication; Dau and Mallek, 2011).

After breeding on more northern nesting areas, a large proportion of Pacific Steller's eiders begin to return to southwest Alaska in late June, in advance of the wing molt (Petersen, 1981). Few of these birds use inner Bristol Bay as they concentrate in the lagoons along the Alaska Peninsula (Dau, personal communication; Mallek and Dau, 2011). Molt migration progresses by sex and age classes, and the actual molt period extends from late July for subadults to October for adult females (Petersen, 1981). Bird numbers increase during fall staging, mainly in Nelson Lagoon and Izembek Lagoon, before moving westward to winter in the Aleutian Islands.

Bristol Bay Lowlands-

Habitats- The Bristol Bay lowlands are characterized by old glacial deposits with moraine lakes and ponds, glacial outwash and riverine deposits along floodplains, and mixed marine deposits near the mouths of the Nushagak and Kvichak Rivers. Landcover is mostly moist and wet tundra between Nushagak and Kvichak Bays, and in a broad region of the upper Mulchatna drainage. Tundra merges into lowland spruce-hardwood forest between the lower Nushagak River and the Wood-Tikchik Lakes, and in the Kvichak Valley to Iliamna Lake (Selkregg, 1976). This subregion has a wide diversity of freshwater lakes and ponds, as well as numerous floodplain wetlands.

Stratum 8 of the AYWBPS generally defines the "lowlands," including the area southwest of Iliamna Lake to the Nushagak Peninsula and extending southwest from Naknek River to Cinder River. Table 8 indicates the average indices and densities of 30 groups (32 species) of waterfowl recorded on aerial surveys flown annually in late May.

Swans- Most swans in the Bristol Bay region are tundra swans that comprise 10-15% of the Western Population which breeds from Kotzebue Sound to the outer Alaska Peninsula and winters from British Columbia to central California (Ely et al., 1997; Pacific Flyway Council, 2001). The most recent ten-year average index of swans from Bristol Bay (AYWBPS Stratum 8) is 15,400 ($0.6/km^2$). Tundra swans arrive as early as mid-March and numbers peak in late April (Wilk, 1988). The majority of swans move north to the Y-K Delta region, but those that breed in Bristol Bay initiate nests in early May and young hatch in early- to mid-June. Because Bristol Bay has an earlier spring thaw, the phenology of local breeding swans is 2-4 weeks earlier than those nesting on the Y-K Delta and northern Alaska. Wilk (1988) provides indications that earlier nesting in Bristol Bay supports larger average brood sizes and higher productivity.

Table 8. Average abundance indices and densities of species/groups recorded in late May on the Alaska Yukon Waterfowl Breeding Population Survey, Bristol Bay Lowlands (Stratum 8)

Species/Group	Long-term Average 1957-2011	Average Index 2002-2011	10-Yr Average Birds/km^2
Mallard	33,100	68,100	2.68
Gadwall	1,400	2,000	0.08
American Wigeon	25,200	55,300	2.16
Green-winged Teal	30,600	71,800	2.80
Blue-winged Teal	0	200	0.01
Northern Shoveler	13,300	33,500	1.30
Northern Pintail	57,300	82,100	3.20
Redhead	0	0	0.00
Canvasback	200	200	0.01
Scaup (Lesser, Greater)	79,800	94,000	3.67
Ring-necked Duck	400	0	0.00
Goldeneye (Common, Barrow's)	4,200	1,600	0.06
Bufflehead	500	300	0.01
Long-tailed Duck	13,700	5,200	0.20
Unidentified Eider	900	500	0.02
Common Eider	0	100	0.00
Spectacled Eider	0	0	0.00
Steller's Eider	0	0	0.00
King Eider	0	0	0.00
Unidentified Scoter	79,400	36,800	1.43
Surf Scoter	n/a [a]	400	0.01
White-winged Scoter	n/a [a]	2,300	0.09
Black Scoter	n/a [a]	37,600	1.47
Merganser (Common, Red-breasted)	2,700	5,300	0.21
TOTAL DUCKS	**346,500**	**497,000**	**19.38**
White-fronted Goose	5,100	5,300	0.21
Canada/Cackling Goose	2,400	2,300	0.09
Emperor Goose	0	0	0.00
(Pacific) Brant	0	100	0.00
TOTAL GEESE	**7,600**	**7,700**	**0.30**
Swan (Tundra, Trumpeter)	12,100	15,400	0.60
Sandhill Crane	3,300	5,300	0.20

[a] Scoters have been recorded by species only since 1993.

Geese- Long-term average indices of geese in the region have been relatively stable over the past 30 years (Table 8), averaging 7,700 geese ($0.3/km^2$) during 2002-11, with greater white-fronted geese over twice as abundant as Canada geese (AYWBPS). Platte and Butler (1995) tallied 4,255 geese ($0.09/km^2$) over a survey area farther inland and estimated composition as 55% white-front and 45% Canada geese. Bristol Bay white-fronts currently comprise only a small portion of the Pacific Flyway population which breeds mostly on the Yukon-Kuskokwim (Y-K) Delta and numbers over 600,000. During the late 1970s and early 1980s, when Pacific white-fronts were overharvested and declined more than 80% (Pacific Flyway Council, 2003; Pamplin, 1986), Bristol Bay white-fronts made up about 15% of the population.

White-fronted geese from Bristol Bay have been shown to be slightly larger than most Pacific Flyway white-fronts from the Y-K Delta (Ely et al., 2005; Orthmeyer et al., 1995) though they are not considered taxonomically separate. Bristol Bay white-fronts also migrate south earlier than others in fall, passing through the Klamath Basin of Oregon and California in September, and overflying the Sacramento Valley where most Pacific white-fronts winter. Bristol Bay birds press further south to winter in the northern highlands of Mexico (Ely and Takekawa, 1996).

The Canada/cackling geese that breed in the Bristol Bay region include Taverner's cackling geese (_Branta hutchinsii Taverneri_) and lesser Canada geese (_Branta canadensis parvipes_), the former found closer to the coast. Taverner's geese breed extensively along the western and northern coastal regions of Alaska, and lesser Canada geese are found throughout Interior Alaska and Yukon Territory, but the breeding ranges of these two populations have not been delineated and there are no reliable population indices (Pacific Flyway Council, 1994). In fall, most lesser Canada geese migrate through Cook Inlet and along the Alaska coast to winter from British Columbia into Washington and Oregon while Taverner's geese staging on the western Alaska Peninsula make a direct migration across the Gulf of Alaska to wintering areas. During winter, most Taverner's and Lessers aggregate with over 250,000 other white-cheeked ("Canada") geese in southwest Washington and western Oregon. They also are found in the upper Columbia River Basin and east of the Cascade Mountains. Intermingling of populations precludes accurate winter inventories.

The smallest subspecies of cackling Geese (_B. h. minima_) migrates through the region en route to and from the Y-K Delta coast where they breed. Cackling geese are assessed annually on their breeding grounds, with survey results indicating substantial increases from a low of <30,000 in 1984 to 150,000-200,000 since 1997. During fall, nearly all of these cacklers historically staged along the Alaska Peninsula near Pilot Point and Cinder River (Sedinger and Bollinger, 1987). Since recovery from a major population decline from overharvest through the early 1980s (Pamplin, 1986), fall staging of cacklers has been more dispersed westward along the Alaska Peninsula (Gill et al., 1997) from which they migrate across the Gulf of Alaska. Prior to the 1980s, cacklers wintered in Central California, but now the majority of cacklers winter in the Willamette Valley of western Oregon and near the Lower Columbia River in southwest Washington (Pacific Flyway Council, 1999).

Brant and emperor geese move through Bristol Bay coastal habitats in spring and fall (see Estuaries and Inner Bristol Bay), but the lowlands are not considered a breeding area. Lesser

snow geese (*Chen caerulescens*) are occasionally seen in Bristol Bay during migration to and from Wrangel Island in Russia.

Ducks- Indices of duck abundance generally have been higher than long-term averages since 1995, as measured by the AYWBPS; the most recent ten-year average is about 497,000 ducks (19.4 ducks/km^2) (Table 8). The most prevalent duck species include greater and lesser scaup (*Aythya marila* and *A. affinis*; 3.7/km^2), northern pintail (*Anas acuta*; 3.2/km^2), green-winged teal (*A. crecca*; 2.8/km^2), mallard (*A. platyrhynchos*; 2.7/km^2), and American wigeon (*A. americana*; 2.2/km^2).

In their expanded survey area, Platte and Butler (1995) estimated averages of 355,200 ducks (7.12/km^2). Duck species composition was similar to the AYWBPS, with the highest average densities ranked as scaup (1.9/km^2), northern pintail (1.1/km^2), green-winged teal (1.0/km^2), and mallard (0.9/km^2). Gadwall (*A. strepera*), wigeon and shoveler (*A. clypeata*), at lower densities, were more prevalent south along the Alaska Peninsula. High to medium densities of scaup were recorded west of Iliamna Lake near the upper Kvichak and Alagnak Rivers.

Scaup- Greater and lesser scaup cannot be differentiated on aerial surveys, but most of the scaup breeding in tundra regions are assumed to be greater scaup (Hodges et al., 1996). The relatively high densities of scaup in the Bristol Bay lowlands recorded on the AYWBPS and expanded surveys suggest that this region hosts a substantial portion of the breeding greater scaup in North America. About 80% of greater scaup migrate across the continent in fall, stopping in the Great Lakes, and wintering along the northeast Atlantic Coast (Kessel et al., 2002). Others winter from south-central Alaska down the Pacific Coast.

Black scoters- Bristol Bay is recognized as one of the most important breeding areas for the western (Pacific) population of black scoters that occupies Alaska and western Canada. The Pacific population may number 200,000-400,000 birds (Bordage and Savard, 1995). The AYWBPS does not provide reliable indices for breeding scoters because it is flown before nest initiation, which is later (June) than other ducks, and because scoters also are found in taiga and boreal habitats outside traditional survey areas. Also, in the past, scoters were not identified to species level during AYWBPS surveys.

Through the Sea Duck Joint Venture, USFWS has been conducting additional aerial surveys designed for scoters in Alaska since 2007 to improve population estimates (Stehn et al., 2010; Stehn et al., 2006), particularly for black scoters that have shown historic declines (Bordage and Savard, 1995). The new surveys have produced recent estimates of 173,000 black scoters on all western Alaska tundra breeding areas (Stehn et al., 2010). Bristol Bay is an important breeding area, containing 46,100 black scoters (0.92/km^2), about 15% of surveyed ducks, in their expanded survey area (Platte and Butler, 1995). Densities were highest in a band from western Kvichak Bay to Lake Iliamna, and also along the western Alaska Peninsula between Egegik and Ugashik Bays.

Inland Tundra/Taiga-
Habitats- The inland subregion of Bristol Bay is underlain by glacial deposits that are interspersed with bedrock formations in the upper Kvichak and Mulchatna drainages. Bedrock

dominates in the montane areas south and east of Lake Clark. Vegetation communities represent a transition from moist tundra to the west into tall shrub habitats and upland spruce hardwood forest; alpine tundra rises into the Aleutian Range (Selkregg, 1976). The subregion has abundant aquatic habitats from alpine lakes and glacial lakes to wet tundra wetlands and floodplain basins along rivers.

Williamson and Peyton (1962) reviewed the characteristics and historical ecological classifications of the Iliamna Lake region, concurring with previous observers that the region's dominant feature is transitional communities where the interior/arctic, southcentral coast forest, and western tundra ecotypes meet. They indicate that neither the dissected Aleutian Range to the east nor the open plateaus to the west serve as barriers for avifauna. These authors describe 12 ecological formations (habitat types) and their associated birds species. Generally, Williamson and Peyton (1962) recorded strong associations of 15 waterfowl species to open lakes and ponds, secondary preferences for streams and rivers by most species, and use of freshwater marshes by dabbling ducks.

Aside from less detailed historical accounts, information on waterfowl distribution and abundance is found in Williamson and Peyton (1962), some aerial survey coverage by Platte and Butler (1995), and a few observations in montane habitats by Ruthrauff et al. (2007).

The most current waterfowl surveys for the inland/Iliamna region are from contract projects for Pebble Limited Partnership (PLP). They include aerial surveys for waterbirds from 2004 to 2006 north of Iliamna Lake during spring staging, breeding/brood surveys, and fall. Some surveys focused on harlequin ducks and tundra swans. Overall, 22 species of breeding waterfowl were recorded (including scaup, goldeneye, mallard, green-wing, pintail), averaging 10 ducks/km^2. Only very general summary information has been made available on the PLP website and in public presentations (Pebble Partnership, 2011).

Swans- Trumpeter swans (*Cygnus buccinator*) are found in the eastern portion of the Bristol Bay region, associated with the forested and taiga habitats typical of the boreal zone. This area abuts temperate coastal forest and coastal marshes occupied by trumpeter swans in Cook Inlet. As their name suggests, tundra swans are primarily birds of open tundra. They have an extensive breeding distribution from the Alaska Peninsula and Bristol Bay coast inland to the Iliamna Lake and Lake Clark regions. The Pacific Coast Population of trumpeter swans has been increasing, including breeders on the Kenai Peninsula, Cook Inlet lowlands and upper Kuskokwim valley. There is increasing evidence that trumpeters are expanding their range westward into tundra swan habitats (Pacific Flyway Council, 2008).

Geese- Lesser Canada geese (*B.c. parvipes*) are found throughout southcentral Alaska and interior portions of southwest Alaska. Though survey data and descriptions of geese are not readily available, it is possible that some Taverner's cackling geese (*B.h. taverneri*) may breed in the inland subregion. The ranges of these similar medium-sized geese have not been delineated. Canada/cackling geese are listed as common in Lake Clark National Park (National Park Service, 2011) and in the Kvichak River valley. Greater white-fronted and snow geese occur during spring and fall migrations to and from Cook Inlet, and brant have been recorded rarely.

Ducks- The densities of dabbling ducks are only moderate in the inland subregion, with mallards, northern pintail and green-winged teal as the most common. Aerial surveys suggest pockets of spring duck habitat near the head of the Kvichak River and the upper portions of the Chulitna and Mulchatna drainages (Platte and Butler, 1995). American wigeon and northern shovelers were less abundant. Scaup and black scoters associated with boreal habitats also occurred in the same general areas, with densities in some up to >8 birds/km^2. Among sea duck species, long-tailed duck, surf scoter, white-winged scoter, common goldeneye (*Bucephala clangula*), Barrow's goldeneye (*Bucephala islandica*), red-breasted merganser (*Mergus serrator*) and common merganser (*Mergus merganser*) were distributed more sparsely and at low densities. Harlequin ducks are found in low densities throughout the Bristol Bay region, using clear high-gradient streams during the breeding season. Harlequins are difficult to detect on aerial surveys due to the habitat they use and are often underestimated.

Nutrients, Trophic Relations and Foods

For waterfowl, body condition, reproductive success, and survival are dependent on the quantity and quality of foods available throughout their annual cycle. Waterfowl typically experience the greatest energetic demands before and during migrations; in the pre-breeding period when resources are needed for egg-laying, incubation, and territory defense; and during summer molt when feather replacement taxes reserves. Though stored reserves (body fat and protein) may be used during migration and incubation, waterfowl need to select habitats that have abundant food resources, be able to efficiently exploit specific foods, and be mobile to optimize seasonal foraging strategies.

Nutrients and Habitat Productivity-

In Alaska, the most productive waterfowl habitats are those that have dynamic nutrient systems that produce seasonally rich plant and animal foods for birds. For example, the mixing of marine nutrients from upwellings and terrestrial nutrients from rivers and streams enrich the productivity of coastal estuaries and lagoons. Large river deltas (Stikine, Copper, Yukon-Kuskokwim, Colville, etc.) are the best examples of complex interfaces of marine and terrestrial nutrients in a matrix of low-lying depositional wetlands, and they support high densities of breeding waterfowl. The estuaries and nearshore waters of Nushagak and Kvichak Bays are enriched by such nutrient mixing (Straty, 1977) in coastal marshes used by swans, geese, and dabbling ducks, and abundant benthic invertebrates for diving and sea ducks.

The productivity of waterfowl habitats in inland-interior regions are also based on dynamic nutrient systems mostly associated with river basin wetlands and floodplains. Within the extensive watersheds of large rivers, nutrient flux (largely nitrogen and phosphorus) is driven by upstream erosion, in-stream transport and seasonal flooding. In forested areas, mosaic patterns of wild fires can also be sources of nutrients for wetlands (Bayley et al., 1992). In the Bristol Bay region, Selkregg (1976) notes a long history of wild fires in the Mulchatna Valley; upland spruce-hardwood forests are found in the upper drainages of the Mulchatna and Nushagak Rivers. Seasonal nutrient inputs refresh and subsidize primary productivity and development of aquatic invertebrates in floodplains and large wetland basins associated with valleys (Heglund, 1992). In the Nushagak and Kvichak River systems, the large volume of sockeye and other salmon species is a significant source of imported nutrients throughout these watersheds (see below).

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Food Habits-

The waterfowl of Bristol Bay exhibit a wide diversity in foraging strategies and food habits; some species tend to be specialists and some are generalists, but nearly all adapt seasonally to different foods. Among swans, geese and ducks during the breeding season, some species defend territories that are selected for sufficient food supplies for nesting adults and growing young; others adapt more social and mobile strategies to take advantage of temporarily abundant foods. During non-breeding periods (migration, molt and winter) waterfowl often aggregate and exhibit fidelity to habitats and sites with reliable food resources.

In general, swans and geese are primarily vegetarians, although adults and young feed opportunistically on insects, aquatic invertebrates and other animal foods especially during breeding and brood-rearing season. Both trumpeter and tundra swans feed on submergent and emergent vegetation year round. The development of cygnets to fledging often extends into fall when their freshwater habitats begin to freeze and they may move to aquatic beds in flowing waters and coastal shallows prior to migration (Limpert and Earnst, 1994.; Mitchell and Eichholz, 2010).

Geese are primarily vegetation grazers, although adults and goslings opportunistically feed on insects and invertebrates. Canada, cackling, and white-fronted geese consume shoots and stems of graminoid plants in typical moist and wet tundra breeding areas. In coastal areas, broods are often brought to wetland basins, tide flats and salt marshes where foods are abundant. During fall staging, Canada and white-fronted geese often frequent uplands to feed on berries. Canada geese, emperor geese and brant are associated with coastal habitats where they rely on salt marsh vegetation, eelgrass beds (*Zostera marina*) in estuaries, and some marine algae (Petersen et al., 1994; Reed et al., 1998).

The three tribes of ducks that use Bristol Bay have very diverse foods habits (Table 9). Dabbling ducks (Anatini) are generally omnivorous, feeding on seeds and aquatic invertebrates, and focusing on high protein foods prior to breeding. Diving ducks (Aythyini) are also omnivorous, but they feed in more open waters for benthic invertebrates and focus on animal foods during staging and wintering on coastal waters. Sea ducks (Mergini) consume mostly animal foods year round, feeding on freshwater benthic invertebrates during breeding and a wide variety of marine invertebrates during staging and wintering on saltwater.

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Table 9. General food habits and consumption of fish by duck species of Bristol Bay.

Common Name	General Food Habits	Consumption of Fish
Dabbling Ducks		
Gadwall	Primarily plant foods with some invertebrates during pre-breeding	Unknown
American Wigeon	Strongly vegetarian with some invertebrates during pre-breeding	Spring herring eggs Oregon coast (Bayer, 1980)
Mallard	Omnivorous, mostly plant seeds and invertebrates, increasing animal foods during pre-breeding	Incidental fish; fall and winter use of salmon eggs and flesh in spawning lakes and coastal waters (Gleason, 2007; Munro, 1943)
Northern Shoveler	Small invertebrates and seeds strained at the surface	Trace of fish in winter
Northern Pintail	Omnivorous, mostly grain and plant seeds with more invertebrates during pre-breeding	Unknown
Green-winged Teal	Omnivorous, mostly plant seeds and invertebrates, increasing animal foods during pre-breeding	Use of salmon eggs and salmon flesh in spawning streams (Gabrielson and Lincoln, 1959)
Diving Ducks		
Canvasback	Omnivorous, mostly plant buds, tubers, root stock and invertebrates, increasing animal foods in pre-breeding	Incidental small fish (Cottam, 1939); alewife fingerlings on fall migration in New York. Spring herring eggs Oregon coast (Bayer, 1980). Salmon flesh Washington coast (Dawson and Bowles, 1909)
Redhead	Omnivorous, mostly plant leaves and stems, invertebrates; increasing animal foods during pre-breeding	Spring herring eggs Oregon coast (Bayer, 1980). Largemouth bass eggs in freshwater (Jarvis and Noyes, 1986). Incidental small fish (Cottam, 1939)
Ring-necked Duck	Omnivorous, mostly plant seeds and invertebrates; increasing animal foods during pre-breeding	Incidental small fish (Cottam, 1939)
Greater Scaup	Omnivorous with varied local and seasonal focus on mollusks, crustaceans, insects	Incidental small fish (Cottam, 1939); fall and winter use of salmon eggs and flesh in coastal streams and lakes (Munro, 1941). Spring herring eggs (Bayer, 1980; Munro, 1941)
Lesser Scaup	Omnivorous with tendency toward animal foods, insects, mollusks, crustaceans	Light use of 8 species of fish and salmon eggs (Cottam, 1939); 3 species of fish during fall in Minnesota (Afton et al 1991); winter scavenging flesh of shad and sunfish (Christopher and Hill, 1988); Spring herring eggs Oregon coast (Bayer, 1980)
Sea Ducks		
Steller's Eider	Mostly animal foods; insect larvae on freshwater; crustaceans, mollusks, other invertebrates on saltwater	Low occurrence of small fish, probably incidental to benthic feeding (Cottam, 1939).
King Eider	Mostly insects and crustaceans with some plant foods on freshwater;	Spring use of lumpfish eggs in Norway; small amounts of sculpins and fish eggs

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Common Name	General Food Habits	Consumption of Fish
	mollusks, crustaceans and diverse marine invertebrates on saltwater.	in Alaska during winter (Cottam, 1939)
Common Eider (Pacific)	Mostly animal foods, mollusks, crustaceans and benthic marine invertebrates	Spring use of herring eggs (Cantin et al., 1974); scarce use of sculpins and sculpins roe in winter (Cottam, 1939)
Harlequin Duck	Foods almost entirely animal; freshwater invertebrates during nesting; diverse mollusks, crustaceans and other marine invertebrates during most of the year	Herring eggs in spring (Munro and Clemens, 1931; Vermeer, 1983); occasional freshwater fish and eggs; fry of char (Kistchinski, 1968); high use of salmon roe in streams in late summer (Dzinbal and Jarvis, 1984); salmon carcasses in streams and estuaries (Vermeer and Levings, 1977)
Surf Scoter	Mostly animal foods, insects and clams on freshwater; mollusks, crustaceans and other invertebrates on saltwater	Minor use of fish, but more than white-winged or black scoters. Herring eggs in spring (Bayer, 1980; Vermeer, 1981)
White-winged Scoter	Mostly animal foods; insects, clams and some plant material on freshwater; mollusks, crustaceans and other invertebrates on saltwater	Minor use of fish on fresh and saltwater; coastal herring eggs in spring (Bayer, 1980; Cottam, 1939; Munro and Clemens, 1931)
Black Scoter	Mostly animal foods; insects,, crustaceans and some plant foods on freshwater; mollusks and crustaceans on saltwater	Some use of freshwater fish eggs (Bengtson, 1971). Spring herring eggs (Bayer, 1980; Munro and Clemens, 1931)
Long-tailed Duck	Mostly animal foods; insects, crustaceans and some plant foods on freshwater; mollusks and crustaceans on saltwater	Some use of freshwater fish (Peterson and Ellarson, 1977). Herring eggs in spring (Munro and Clemens, 1931) and some bottom fish on saltwater in winter (Cottam, 1939; Sanger and Jones, 1984)
Bufflehead	Mostly animal foods with some plant material seasonally; insects and crustaceans on freshwater; crustaceans and mollusks in saltwater	Minor use of fish on freshwater; salmon eggs in coastal streams; fall and winter use of small fish; herring eggs in spring (Bayer, 1980; Munro, 1942; Vermeer, 1982)
Common Goldeneye	Mostly animal foods; insects, mollusks and crustaceans on freshwater; crustaceans and mollusks in saltwater	Diverse small fish and roe in freshwaters and saltwater (Cottam, 1939; Jones and Drobney, 1986); salmon eggs and flesh on coastal lakes and rivers (Taverner, 1934); herring eggs in spring (Munro and Clemens, 1931; Vermeer, 1982)
Barrow's Goldeneye	Mostly animal foods; insects, mollusks and crustaceans on freshwater; crustaceans and mollusks in saltwater	Herring eggs in spring (Munro and Clemens, 1931; Vermeer, 1982); small numbers of sculpins taken; salmon eggs and parr on freshwater (Fitzner and Gray, 1994; Munro, 1923); salmon flesh (Cottam, 1939)

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Common Merganser	Primarily small fish, also insects, mollusks, crustaceans, and small vertebrates	Very diverse fish prey. Salmon are most important in some regions (Munro and Clemens, 1932; Munro and Clemens, 1937; Salyer and Lagler, 1940)
Red-breasted Merganser	Primarily small fish, also insects, mollusks, crustaceans, and small vertebrates	Diverse fish prey. Salmon are important in some regions (Munro and Clemens, 1939; White, 1957). Also take herring and roe

Information obtained primarily from species accounts in the Birds of North America (A. Poole, Ed.). Cornell Lab of Ornithology, Ithaca, NY. Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/

Importance of Marine-Derived Nutrients (Salmon and Herring) to Waterfowl-

Waterfowl benefit from salmon as both direct sources of prey and carrion and indirect nutrient drivers of aquatic systems (i.e., supporting invertebrate prey species and riverine plant communities). Roughly 30-40 million salmon spawn annually in the Kvichak and Nushagak systems (Hilborn et al., 2003; Ruggerone et al., 2010), importing perhaps 20 million kg (44 million pounds) of nutrients throughout the watersheds. The fate of these nutrients (primarily nitrogen and phosphorus) is divided among the breakdown of carcasses (Cederholm et al., 1989; Cederholm et al., 1999) and deposition in drainages, the outmigration of smolts (Crawford, 2001; Moore and Schindler, 2004), and discharge into estuaries. This large influx of nutrients and net gain to riverine and terrestrial systems strongly affects a wide variety of plants and animals, including waterfowl (Gende et al., 2002; Holtgrieve, 2009; Willson et al., 1998; Willson and Halupka, 1995).

Of the 24 duck species that regularly occur in Bristol Bay, at least eleven species are known to prey on salmon eggs, parr, smolts, and scavenge on flesh of spent carcasses (Table 9). Of these, greater and lesser scaup, harlequin duck, bufflehead, common and Barrow's goldeneyes, and common and red-breasted mergansers exhibit directed foraging on salmon. Among dabbling ducks, mallards feed most on salmon because they are distributed across a diversity of summer habitats in spawning areas, and they are the principal wintering dabbling duck on the North Pacific coast where fall-winter salmon runs occur.

From early May through June, salmon smolts emigrate from Bristol Bay rivers, providing abundant prey (325 million smolt in the Kvichak) (Crawford, 2001) for fish predators like mergansers (Munro and Clemens, 1932; Munro and Clemens, 1937; Munro and Clemens, 1939; Salyer and Lagler, 1940; White, 1957; Wood, 1987a; Wood, 1987b). Other duck species may prey on smolt incidentally.

From late June through early September, salmon eggs are readily available on and downstream of spawning beds. These eggs are a seasonally rich food source for harlequin ducks, goldeneyes and scaup that frequent rivers and streams (Cottam, 1939; Dzinbal and Jarvis, 1984; Munro, 1923) and probably for other opportunistic ducks.

From mid-July through September, salmon carcasses are abundant in streams, rivers and spawning lakes. Though the scientific literature is scarce on this subject, species ranging from

dabbling ducks (mallard, green-winged teal) and diving ducks to sea ducks that inhabit spawning waters opportunistically scavenge easy protein-rich meals (Table 9).

Harlequin ducks offer an example of a waterfowl species that utilizes salmon in all life stages. Harlequins breed in high gradient streams in the upper reaches of drainages (Robertson and Goudie, 1999), and they forage in portions of rivers and streams occupied by salmon. In the Kolyma Highlands in Russia, harlequins focused on fry of Dolly Varden (*Salvelinus malma*) and white-spotted char (*S. leucomaenis*) (Kistchinski, 1968). Gudmundsson (1971) noted a relationship between harlequin duck nesting areas and Atlantic salmon (*Salmo salar*) spawning areas in Iceland, but thought that ducks and salmon fry preyed on the same insect larvae. Dzinbal and Jarvis (1984) demonstrated that harlequins breeding in the short streams of northern Prince William Sound depended heavily on the dislodged eggs of pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon in the lower stream reaches from the first week of July to early August. In their study, the drifting biomass of salmon eggs exceeded the biomass of invertebrates in late July and early August. Harlequin ducks also scavenge from salmon carcasses from August through September (Vermeer and Levings, 1977). Winter diets did not include notable occurrence of fish (Fischer and Griffin, 2000; Vermeer, 1983).

Spring spawning of Pacific herring (*Clupea pallasi*) along Alaska coasts provides abundant food for waterfowl and many other waterbirds in need of energy during migration, and sea ducks follow the progressive spawning northward (Lok et al., 2008). Though the waters of inner Bristol Bay are turbid and not conducive to herring spawning, small concentrations may be found. The region's center of herring activity is the Togiak district west of Cape Constantine from Kulukak Bay to Cape Pierce (ADF&G, 2011c). Sixteen of Bristol Bay's duck species feed on herring and herring roe during spring (Table 9; (Bayer, 1980; Lok et al., 2011; Lok et al., 2008; Munro and Clemens, 1931; Vermeer, 1983)).

Populations, Subpopulations, and Genetics

Among waterfowl, the designation of subspecies, populations, and subpopulations has been applied through increasing research on genetic diversity and relatedness; a long history of morphological measurements; and evaluation of cohesiveness, philopatry, and annual distributions of birds from traditional banding and marking studies. Overall, few population units below the species level have been established for swans, geese, and ducks, probably because their extensive migrations and mobility across broad ranges provide genetic homogeneity. The American Ornithologist's Union (AOU) no longer taxonomically designates subspecies (American Ornithologists' Union, 2011) because of the difficulty in differentiating valid subunits and the dynamic nature of evolving groups.

In some cases, subspecies and populations have been defined when genetic, morphological and observational data support designations that are practical for population management, yet are provisional in terms of taxonomy. Population units also have been designated for purposes of monitoring biodiversity by programs such as the Alaska Natural Heritage program (Alaska Natural Heritage Program, 2011), but under varying scientific standards that may be less rigorous than taxonomic determinations. In addition, populations may be defined and designated for protection under the Endangered Species Act without strict evidence of discreteness or

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genetic distinction. Following is a summary of current understanding of population structuring in the principal waterfowl species of Bristol Bay.

Swans-
Few distinctions have been made among trumpeter or tundra swans across their ranges. Trumpeter swans in Alaska are part of the Pacific Coast Population (PCP) that constitutes over 80% of the species in North America. Recent genetic studies (Oyler-McCance et al., 2007) indicate that PCP birds are distinguishable from Rocky Mountain Population (RMP) trumpeters that range from Yukon Territory south to Wyoming and Utah, but within Alaska trumpeters are fairly homogenous through the Interior and Cook Inlet. Copper River Delta breeders were somewhat unique because of their geographic isolation. Samples were taken from Susitna Basin and the Kenai Peninsula, but not from the eastern Bristol Bay region. Based on banding and marking studies, tundra swans in southwest Alaska are affiliated with the Western Population (WP) found wintering west of the Rocky Mountains (Pacific Flyway Council, 2001). The small non-migratory group on the end of the Alaska Peninsula is considered part of the WP, not a separate entity.

Geese-
The taxonomy of Canada geese has long been debated, but the recent species separation of cackling geese (_B. hutchinsii_) from Canada geese (_B. canadensis_) is based on extensive genetic studies (Paxinos et al., 2002; Scribner et al., 2003) that support divergence of three small subspecies (_hutchinsii_) from three larger subspecies (_canadensis_) during the last glacial period. The coastal Taverner's (cackling) goose and inland lesser (Canada) goose breeding in the Bristol Bay region, as well as the migrant Cackling (cackling) goose that passes through, have been managed somewhat separately for over 60 years. The extensive historical banding information and genetic evidence, warrants recognition of these populations among six white-cheeked goose populations in Alaska.

As mentioned previously, white fronted geese breeding in Bristol Bay are slightly different in morphology and migration patterns from other Pacific white-fronts nesting on the Y-K Delta, but the differences do not rise to the level of taxonomic significance, nor can they practically be managed separately (Ely et al., 2005; Orthmeyer et al., 1995; Pacific Flyway Council, 2003).

Dabbling and Diving Ducks-
Historically, there has been little to support identification of distinct populations among dabbling ducks (tribe _Anatini_) and diving ducks (tribe _Aythyini_) largely because of their extensive mobility and exchanges across flyways. No population structure has been suggested among these ducks for the Pacific Flyway or Bristol Bay, though extensive genetics studies have not been conducted.

Sea Ducks-
Over the past 10 years, declining trends in most sea duck species (tribe Mergini) and the listing of spectacled and Steller's eiders under ESA have prompted research into the structure and diversity of sea duck populations. In general, sea ducks are known to be quite philopatric to breeding, molting and wintering areas, suggesting the potential for discrete population units. In addition, sea ducks from broad breeding ranges aggregate in winter, making winter a critical

period of social and genetic interchange. These unique characteristics are important for understanding the biology of sea ducks and adopting effective management regimes.

The biology and population dynamics of harlequin ducks are not well understood, but they breed in the upper high-gradient drainages of Bristol Bay and occur in the upper bay, Alaska Peninsula, and Cook Inlet during the non-breeding season. Though these birds are generally segregated by river drainage during breeding and they demonstrate fidelity to wintering areas (Esler et al., 2000), dispersal occurs across regions (Cooke et al., 2000). No evidence has been found to genetically distinguish wintering harlequins from Prince William Sound, Kodiak and Katmai areas (Lanctot et al., 1999). This suggests that gene flow likely has occurred across broad areas and regionally discrete populations have not developed.

In a study of genetic structure among king eiders, samples were analyzed from Holarctic breeding areas from northeast Russia east to Greenland, and wintering areas in the Pacific and Atlantic sides of North America (Pearce et al., 2004). Results showed little genetic structuring across the range, indicating that historical or current mobility among regions has not produced discrete populations, particularly in western North America including the aggregations of molting and wintering birds of Bristol Bay.

The population structure of Steller's eiders has been of great interest to assess the status and prospects of the threatened Alaska-breeding component, particularly the small group breeding near Barrow. In a study that genetically compared samples from breeding and wintering areas of the Atlantic population (Russia-Norway) and the Pacific population (Russia-Alaska), some differentiation was found between the two greater populations, but no sign of subpopulation structure (Pearce et al., 2005). Similar to the situation with king eiders, genetic differentiation could develop in the future if natural or anthropogenic factors provide isolation of breeding groups.

Human Use

Bristol Bay waterfowl provide viewing, educational and research values, and harvest opportunities to people in Alaska, Russia, Canada, the western U.S., and Mexico. As described above, Bristol Bay is uniquely positioned to host a great diversity of waterfowl that breed, winter, or pass through the region. This includes birds associated with Arctic breeding grounds, the Aleutian Islands, the exceptionally productive tundra habitats of western Alaska, and birds that winter as far south as Mexico and east to Chesapeake Bay. Though most of the common waterfowl species of North America occur in the region, species such as swans, emperor geese, and eiders are especially appreciated for their aesthetic, scientific and cultural values. The richness and abundance of waterfowl from the region supports significant subsistence and recreational harvests that are important economically and traditionally throughout western North America.

Nonconsumptive Uses-
Birds that breed in or pass through Bristol Bay are subjects of wildlife viewing opportunities throughout their annual cycles, from Alaska to Mexico. During spring and fall migration, and during winter, Bristol Bay birds stop at many local, state, and federal parks and wildlife areas featuring viewing and interpretive facilities. For some species, special community events revolve

around the occurrence of migrating birds. For example, there are brant festivals in British Columbia, Puget Sound, and northern California, and brant are an attraction with whale watchers in Baja California. Such events and numerous local viewing programs are also common for swans, aggregations of geese, and sandhill cranes that breed in the Bristol Bay lowlands.

Recreational Harvest-
Because Bristol Bay is an important breeding and staging area for ducks and geese, birds produced in or supported by the region comprise a notable contribution to fall and winter harvests in the Pacific Flyway from Alaska to Mexico. Waterfowl harvest data have been collected by USFWS in Alaska since the early 1960s through a national mail questionnaire survey (MQS) of federal duck stamp buyers. Species composition of the harvest was estimated from duck wings and goose tails from a Parts Collection Survey (PCS). From 1971 through 1997 ADFG also conducted a mail questionnaire survey of hunters. Since 1998, waterfowl harvests have been estimated by USFWS through the national Harvest Information Program (HIP), based on a sample of all registered migratory bird hunters. The objective of all these surveys was to produce reliable estimates of duck and goose harvests at the statewide level.

There are no reliable estimates of fall duck and goose harvests in the Bristol Bay region. Although the ADFG survey and federal MQS surveys collected harvest data by regions, the hunter sampling rates were not sufficient to provide more than a general sense of harvest across the state. Bristol Bay was only part of a large sampling region named "Alaska Peninsula" that extended west to Unimak Pass where ADFG data indicate that 4,000-5,000 ducks and 2,000 geese were harvested annually. Through the 1990s, this amounted to roughly 5% of Alaska's fall duck harvest and 20-25% of the goose harvest. There are no recent regional harvest data.

Beyond southwest Alaska, birds that use Bristol Bay for some part of their life cycle contribute an unknown portion of fall harvests in south-central and southeast Alaska, which typically represent 60-70% of the statewide duck total (~70,000) and 30-40% of the statewide goose harvest (~6,100) (USFWS, 2010a). There is no practical way to estimate the proportion of ducks and geese from Bristol Bay harvested in the western states or other jurisdictions. Waterfowl banding has not been sufficient in the Bristol Bay region to undertake analysis of harvest derivation for the Pacific Flyway.

Since 2001, a fall tundra swan season has been open in Game Management Unit 17, with registration permits required. The unit includes the Togiak, Wood, and Nushagak drainages inland to Lake Clark. On average, fewer than 60 permits have been issued annually, and reported harvest has been less than ten swans per year (ADFG, unpubl. data). A small number of tundra swans harvested in Montana, Utah, and Nevada are derived from Bristol Bay.

Subsistence Harvest-
Harvest of waterfowl and other birds has been an important component of Bristol Bay's traditional subsistence culture and economy. Although spring and summer hunting occurred historically and continues, it was largely illegal after passage of the Migratory Bird Treaty Act of 1918. Fall and winter hunting, beginning September 1, has been allowed under federal and state regulations. In 1997 the United States Senate ratified Protocols that amended the migratory bird treaties with Canada and Mexico. This action authorized the USFWS to open a legal, regulated

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spring and summer subsistence season for migratory birds in Alaska during 2003, the first in over 80 years. The Alaska Migratory Bird Co-Management Council (AMBCC) was formed, composed of USFWS, ADF&G, and 12 regional representatives to establish a body of subsistence hunting regulations and undertake the vital task of assessing spring and summer subsistence harvests to meet intentions of the amended treaties.

During the 1980s, ADF&G worked with federal agencies, Alaska Native regional organizations, and village governments to conduct subsistence harvest surveys of 151 rural communities in Alaska and they characterized the levels and nature of migratory bird subsistence harvest in Alaska, including Bristol Bay (Wolfe et al., 1990). In response to an intensive goose conservation program on the Y-K Delta, cooperative village harvest surveys were initiated across the region and eventually expanded to Bristol Bay villages that harvested the same goose populations (Wong and Wentworth, 1999). These surveys, begun in 1995, gathered harvest data by subregions, including Togiak, Dillingham, Iliamna, and villages in the Nushagak drainage and on the Alaska Peninsula.

In a review of historical and recent harvest information, the AMBCC found the available data to be insufficient to address management needs, so it designed a comprehensive statewide survey protocol (Alaska Migratory Bird Co-Management Council, 2003), including Bristol Bay communities on a rotating basis. Statewide subsistence harvest surveys were implemented annually from 2004 to 2009, although they were not fully funded and implemented to full performance standards.

In general, the seasonal harvest of migratory birds in the Bristol Bay region is most prevalent in spring, with a few species taken in summer, and increased hunting during fall migration and winter (Wolfe et al., 1990). The importance of the spring harvest reflects the abundance of birds during spring migration and traditional need for fresh meat after winter supplies have been depleted. For the Bristol Bay/Iliamna region (not including Alaska Peninsula), Wolfe et al. (1990) estimated annual harvests in the late 1980s of about 8,800 ducks, nearly 2,000 geese, 100 swans, and 1,100 waterfowl eggs. About 70% of households used birds; waterfowl provided 3.4 lbs of meat per capita.

Conservation concerns in the late 1980s prompted a statewide assessment of harvests for Pacific brant, emperor geese, and eider species (Wolfe and Paige, 1995). This study characterized harvest of these species circa the early 1990s and presented harvest estimates by regions (including North Bristol Bay, South Bristol Bay, and Lake Iliamna-Nushagak) and some communities from ADFG and USFWS surveys during 1983-94. Harvest estimates for Bristol Bay subregions provide totals for relative comparisons to other parts of the state, but also reflect the seasonal availability of species within the region.

Brant harvest was highest (~300) in the North Bristol Bay area where spring staging is concurrent with seal hunting (Schichnes and Chythlook, 1988), but was low in South Bristol Bay because most brant bypass that part of the Alaska Peninsula. Brant were rare inland in the Iliamna-Nushagak region. Emperor geese, which are closely tied to the coast in transit to and from the Aleutian Islands, provided harvest for North (~300) and South (~200) Bristol Bay, but were rare inland. Because of diminished numbers, all hunting of emperor geese was closed in

1986. Eiders were harvested most in North Bristol Bay (~850) where king eiders are abundant during spring and molt in Nushagak and Kvichak Bay, and common eiders stage during migrations. Eider harvest was low in South Bristol Bay where king and common eiders are more transient. Only common eiders (~250) were recorded for the Iliamna-Nushagak region, probably representing either inland migrant birds from lower Cook Inlet or inland households hunting in coastal areas.

Harvest data from 1995-2005 were collected by subregion, including Dillingham, Nushagak River and Iliamna subregions (Wentworth, 2007; Wong and Wentworth, 1999). Estimated annual harvests included ~10,000 ducks (mostly dabbling ducks, with ~600 scoters, 100-200 eiders, and up to 190 harlequin ducks); 2,500-2,900 geese (up to 1,000 white-front, 800 Canada/cackling, 180-230 brant); up to 300 tundra swans; and fewer than 500 waterfowl eggs.

As part of the statewide AMBCC harvest survey program, Bristol Bay communities were sampled during 2004 to 2008, including a Southwest Bristol Bay Subregion from Togiak south to Port Heiden covering King Salmon and 20 villages in the Nushagak and Kvichak drainages, and a Dillingham Subregion sampled every other year. Recent harvest estimates and seasonality of species harvests are found in Naves (2010a, b). Approximate five-year average harvests for the villages are: ducks – 10,200 (includes 600 scoters, 1,600 eiders); geese – 5,200 (includes 2,700 Canada, 1,300 white-fronts, 1,100 brant); swans – 270; and waterfowl eggs – 800. Dillingham was surveyed on a rotational schedule (2005, 2007, 2008); results indicated estimated harvests of 1,000-5,000 ducks, 500-800 geese, up to 50 swans, and less than 100 waterfowl eggs (Naves, 2010a; Naves, 2010b).

It is difficult to precisely characterize subsistence harvest of waterfowl in the Nushagak and Kvichak watersheds and the greater Bristol Bay region because of subregional differences in the geographic diversity and seasonal availability of waterfowl species and other wildlife resources, as well as differences in cultural preferences and practices (Wright et al., 1985). In addition, local and regional harvests of migratory birds vary considerably year-to-year because of variations in bird abundance; timing, rates, and patterns of migrations; and seasonal hunting conditions (Wolfe et al., 1990). Assessments of changes or potential changes to subsistence uses of migratory birds will rely on updated status information for migratory bird populations, review of data from the AMBCC community harvest survey program (Naves, 2010b), and compilation of historic and current harvest data for subregions and communities (Behnke, 1982; Fall et al., 2006; Fall et al., 1986; Schichnes and Chythlook, 1988; Schichnes and Chythlook, 1991).

BALD EAGLES

Introduction

Bald eagles (*Haliaeetus leucocephalus*) range across North America, but are most abundant in Alaska, where approximately half of the world population occurs. During the first half of the 20th century in Alaska, the abundance of bald eagles and their attraction to human food sources made them easy prey for bounty hunters (Hodges and Robards, 1982). Since even before the end of the bounty days, however, they have been valued by Americans for their stately appearance, and especially for their intrinsic association with wilderness (King, 2010). Bald eagles and their nests receive extra protection above and beyond that afforded to other migratory birds by the Migratory Bird Treaty Act (16 U.S.C. §§ 703–712). The Bald and Golden Eagle Protection Act (16 U.S.C. 668-668c), enacted in 1940 and amended several times since then, establishes federal responsibility for the protection of bald and golden eagles and requires consultation with the USFWS to ensure activities do not adversely affect bald eagle populations. The Act prohibits anyone, without a permit issued by the Secretary of the Interior, from "taking" bald eagles, including their parts, nests, or eggs. It provides criminal penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald eagle ... [or any golden eagle], alive or dead, or any part, nest, or egg thereof."

A large apex predator, as well as an opportunistic scavenger, the bald eagles is a key species of most of the regional food webs across coastal Alaska, from the Aleutians to Southeast. Bald eagles were proposed as a management indicator species (MIS) for all National Forest lands in Alaska (Sidle and Suring, 1986) and selected as a MIS for the Tongass National Forest (USFS, 2008). They are also included as a "vital sign"[3] for long-term monitoring in the southwest Alaska national parks (Bennett et al., 2006). The purpose of this paper is to provide a characterization of bald eagles in the Nushagak and Kvichak watersheds, with particular emphasis on their ecological relationships with MDNs.

Habitat

Bald eagles are well-known for their association with water. In the Pacific Northwest most nests are within 1.6 kilometers of large waterbodies (Anthony et al., 1982) and in Alaska they are almost always found within 200 meters of a stream, lake, or ocean shoreline (Hodges and Robards, 1982; Stalmaster, 1987; Swaim, personal communication). In the Bristol Bay watershed they inhabit the spruce and mixed spruce/broadleaf forests along major rivers, streams, and lakes of the Bristol Bay Lowlands, upper Alaska Peninsula, and Lime Hills eco-regions (ADF&G, 2006), as well as coastal areas of Bristol Bay.

Throughout most of their range, bald eagles nest in forested habitat associated with riparian and beach areas (Buehler, 2000; Stalmaster, 1987). The significance of shoreline nest sites appears to be strongly related to foraging opportunities these areas provide (Armstrong, 2010). Commonly

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[3] Defined as "a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values."

used foraging areas are open sites where prey or carrion can be seen and accessed by these large birds. These are often areas that provide prey aggregations, accessible to many bald eagles at once. In Alaska, these areas include lakes, rivers, oceans, and their shorelines, beaches, and bars (Stalmaster, 1987). On the Kenai NWR, nests are located near clear, relatively shallow streams with spring and fall fish runs (Bangs et al., 1982a). While bald eagle nest sites are positively correlated with water, they tend to be negatively correlated with lands impacted by timber harvest and other human uses (Anthony and Isaacs, 1989; Livingston et al., 1990).

In Alaska, where suitable trees are present, bald eagles build their enormous nests near the tops of live trees, typically in one of the tallest of the stand (Bangs et al., 1982a; Ritchie, 1982; Stalmaster, 1987). Where large trees are absent, they nest on ridges, hillsides, small islets, or sea stacks (Savage, personal communication; Suring, 2010). Around Lake Clark and its drainages, most nests are reported to be in balsam poplar and spruce trees (Wright, 2010). Monitoring in LCNPP since 1992 identified black cottonwood as the predominant substrate for coastal nests; interior nests were more equally divided between cottonwood and spruce (from Witter and Mangipane 2011, in preparation). Of the 165 known bald eagle nest sites on Togiak NWR, most (~86%) are in balsam poplar trees; 8% are in spruce and 6% are located on the ground (Swaim, personal communication).

On Kodiak NWR, one-third of bald eagle nest sites are not located in trees (Zwiefelhofer, 2007). In the Bristol Bay area, at least one ground nest has been noted on an islet in Tikchik Lake (Wright, 2010) and one on an islet in Katmai NPP (Savage, personal communication). At least two ground nests have been documented on Flat Island, in interior LCNPP, although each was occupied for only one year (one was successful and the other failed). Also, there are multiple years of data on two coastal ground nests near Tuxedni Bay in LCNPP. A third coastal ground nest was found near Difficult Creek in 2011 and was successful that year (Witter, personal communication). Besides nest platforms, bald eagles need perches and, often, communal roosts. In Alaska, bald eagles commonly perch in large spruce or cottonwood trees, often with a good view of foraging waters. Bald eagles often perch for 90% of the daylight hours (Stalmaster and Gessaman, 1984), with these locations serving as sites for resting/loafing, foraging/hunting, feeding, look-outs/sentry posts, displaying (territoriality), and thermal regulation (heating or cooling) (Stalmaster, 1987).

The extent of communal roosting is not well-known for the Nushagak and Kvichak watersheds. In general, though, breeding bald eagles roost at the nest tree or on other large trees within their territory. Non-breeding bald eagles often retire to communal roosts at night, usually in large spruce or cottonwoods trees. They may be near a foraging area, but are not as closely associated with shorelines as perches and nest trees (Stalmaster, 1987). Non-breeding bald eagles also regularly feed, rest, and roost along gravel bars and gravel shorelines (Hansen et al., 1984). On the Naknek River in March and April, communal roosts are located on hillsides with shrubs and some balsam poplars (Savage, personal communication). These are often on south-facing slopes that overlook the river.

An abundant, readily available food supply in conjunction with one or more suitable night roost sites is the primary characteristic of winter habitat. The majority of wintering bald eagles are found near open water, where they feed on fish, marine invertebrates, and waterfowl and

seabirds, often taking dead, crippled, or otherwise vulnerable animals (Buehler, 2000). Over-wintering on the breeding grounds may provide a competitive edge in territory selection and with early initiation of nesting (Ritchie and Ambrose, 1987).

The proportion of bald eagles that over-winter in the Nushagak and Kvichak watersheds is not well-understood, and potential links between over-wintering and open water or winter prey accessibility remain to be studied. Ritchie and Ambrose (1987) reported that records of bald eagles over-wintering in northern boreal forests are rare and that one reason for this fact is that water bodies are frozen. They observed bald eagles in winter along the Tanana River in Interior Alaska, where open water probably provides access to spawning salmon and waterfowl. Bald eagles often congregate along the ice/open water interface on the Naknek River, where wintering common mergansers (*Mergus merganser*) and common goldeneyes (*Bucephala clangula*) are often found. The 1986 to 2010 King Salmon–Naknek Christmas bird counts reported from zero to up to 48 adult bald eagles (average 18) (Savage, personal communication). Some over-wintering occurs in Dillingham and the surrounding area, but in much lower densities than found in summer. Some of those over-wintering eagles obtain human garbage at the city dump (Swaim, personal communication).

Food Habits

Diet- Bald eagles are primarily fish eaters (Armstrong, 2010). They do, however, have a variable diet that can include birds, mammals, and crustaceans, and, as noted above, even human garbage (Anthony et al., 1999; Knight and Knight, 1983) (also see Stalmaster 1987 and Armstrong 2010 for summaries).

Food habits vary spatially according to specific prey availability and abundance at the site. Bald eagles nesting near and foraging at seabird colonies during the summer may take primarily bird prey (DeGange and Nelson, 1982). In the Pacific Northwest, diet varied among sites, with bird prey items found under nests generally out-numbering fish items (Knight et al., 1990).[4] Birds likely also out-number fish as prey at some sites on Togiak NWR, including Cape Peirce and Cape Newenham, which support high densities of breeding seabirds (Swaim, personal communication).

The diet of bald eagles tends to vary temporally, as well, depending on prey availability and abundance. Nesting bald eagles rely primarily on the availability of salmon resources (Hansen, 1987). Inland bald eagles whose nests are close to spawning streams have higher nesting success than those with more distant nests (Gerrard et al., 1975). When salmon resources are scarce during late winter and early spring, coastal populations of bald eagles often shift their diet to birds (Isleib, 2010; Wright and Schempf, 2010). In one study, birds averaged nearly 20% of stomach contents by volume over the course of a year, but could range up to 86% and be especially high during the colder months (Imler and Kalmbach, 1955). In other areas, mammalian prey may be utilized in winter, because it is as available, or more available, than birds. For example, on the Kenai NWR, bald eagles may seasonally shift from a diet of primarily fish to snowshoe hare (*Lepus americanus*) or mammalian carrion (Bangs et al., 1982a).

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[4] Note that fish and other soft-boned or bodied prey may be commonly under-counted in both stomach-content and under-nest methodologies (Ritchie 1982, Knight et al. 1990).

Specific information regarding bald eagle diet variability in the Nushagak and Kvichak watersheds is generally not available. Eagles in the Bristol Bay watershed area eat all five species of Pacific salmon (Savage, personal communication). Bald eagles in the winter along the Naknek River have been observed to take small fish, which may include eulachon (*Thaleichthys pacificus*) (Savage, personal communication). Pacific herring (*Clupea pallasi*) may also be an important resource for bald eagles in the Togiak area. In early spring Savage has also observed bald eagles catching large rainbow trout (*Oncorhynchus mykiss*). Bald eagles in Bristol Bay may also scavenge dead marine mammals (Savage, personal communication).

Independent of prey availability, energy requirements may influence prey selection at some level as well. During the breeding season many bald eagles choose large fish over small fish (Jenkins and Jackman, 1994). Diets of nesting bald eagles are much more variable than those of non-breeders (Hansen et al., 1984; Hansen et al., 1986). Non-breeders are able to range farther for preferred food items (e.g., in late fall birds may leave the Chilkat Valley in southeast Alaska to go to British Columbia and Washington, where salmon may still be available). Feeding of young is, as Stalmaster (1987) says, "an enormous chore" and breeders may exploit a variety of food resources within their home range.

Significance of MDNs- Fresh salmon and salmon carcasses provide an ideal food resource for bald eagles, because they are large fish that become available in great numbers when they enter shallow water to spawn. Shallow water increases the likelihood that living fish will be available to bald eagles because the limited depth of water brings fish closer to the surface (Livingston et al., 1990). Returning salmon die after spawning in natal streams, providing a significant seasonal pulse of MDNs, including nitrogen and phosphorous, to the generally oligotrophic streams and lakes of northern Pacific watersheds (Hilderbrand et al., 2004; Naiman et al., 2002b; Willson et al., 1998). Spawned-out salmon carcasses accumulate on stream banks, river bars, lake and ocean shores, and tidal flats (Armstrong, 2010). Although spawned-out salmon are low in fat and considered a relatively low-energy food source (Christie and Reimchen, 2005), their large size, availability, sheer numbers, and other factors (even cold air temperatures, which can increase the efficiency of digestion of some prey (Stalmaster and Gessaman, 1982)), contribute to their value. Salmon are approximately 79% edible flesh, compared to 71% for hares and 68% for ducks (Stalmaster, 1981). Although metabolizable energy is lower for salmon than for hares or ducks, their greater size means that a bald eagle would require only 57 salmon in one year, compared to 87 hares, or 135 ducks (Stalmaster, 1981; Stalmaster and Gessaman, 1982).

Armstrong (2010) reported that several studies have correlated bald eagle abundance with the abundance of spawned-out salmon. Simply put, bald eagles in southeast Alaska, the Kenai NWR, and many other parts of their range likely depend on salmon (Armstrong, 2010; Bangs et al., 1982b). The nature of the relationship that bald eagles have with salmon, however, is complex (Hansen et al., 1986). The variable nature of salmon (and other bald eagle food sources) apparently causes bald eagles to be limited by food availability (Stalmaster and Gessaman, 1984). The abundance of salmon affects not only bald eagle population and distribution, but also breeding and behavior. Bald eagles, in turn, affect the riparian ecosystem and other areas where they may range by distributing the MDNs in their excretions (Gende et al., 2002).

Bald eagles in Alaska also congregate to feed on other species of anadromous and shallow-water spawning fish, particularly Dolly Varden (*Salvelinus malma malma*), Pacific herring, and eulachon (Armstrong, 2010). Armstrong (2010) also summarized the importance of Pacific sand lance (*Ammodytes hexapterus*) to bald eagles and other marine-associated birds and mammals.

Foraging Methods- Bald eagles are opportunistic foragers that exhibit rather complex social feeding behaviors. They use a variety of methods to obtain food, including active hunting and killing, scavenging of carcasses, and theft (pirating or kleptoparasitizing) from other eagles or species (Stalmaster, 1987). They are visual predators that locate their prey by sight. Foraging methods chosen by bald eagles vary according to both complex relationships among other eagles and with other predators or competitors, as well as seasonal variability of food sources. Bald eagles may search for prey themselves or follow other birds, or even mammals, to a concentrated food source (Harmata, 1984; Knight and Knight, 1983; McClelland et al., 1982). Also, as summarized in Armstrong (2010), bald eagles will not only steal fish or force other predators away from fish, but will also exploit fish injured or driven to the surface by others, and scavenge crippled or dead fish or fish parts left by other predators such as humans or bears. Bald eagles in the Chilkat Valley of southeast Alaska typically competed amongst themselves for salmon (Hansen et al., 1984). Dominance in bald eagles may be based on several conditions, but often includes age and size (Garcelon, 1990; Stalmaster, 1987).

Salmon returning to spawning streams are a relatively easy food source for bald eagles, because the fish are found either in shallow waters, swimming or floating near the surface, or washed up or stranded on streambanks (McClelland and McClelland, 1986). Besides their size, abundance, and availability in shallow water, other unique aspects of salmon life history may contribute to their importance to bald eagles. For example, large numbers may be frozen into river ice in the winter, becoming available as food sources again in spring (Hansen et al., 1984). Brown bear pull salmon from holes too deep for eagles to access, often transporting and discarding portions of carcasses to other locations, where eagles then scavenge them (Armstrong, 2010). Armstrong (2010) stressed what he believes to be a particularly important relationship with bears (*Ursus* spp.), which scoop salmon out of deep pools, where they may be inaccessible to bald eagles, and then often eat only the brains and eggs, leaving a significant proportion of the salmon flesh for the birds.

According to Stalmaster (1987), bald eagles, in general, appear to prefer stealing of food over scavenging, and scavenging over hunting. Hansen et al. (1984) observed higher frequencies of stealing over scavenging of salmon carcasses in the Chilkat Valley in southeast Alaska, even though the cost and benefits of both may be equal. However, others have found that, when food is scarce, bald eagles will choose scavenging over stealing, if both methods are available (Knight and Skagen, 1988). Wright and Schempf (2010) state that during seasons of food scarcity, feeding strategy may switch to more active hunting, particularly of large gulls and waterfowl, and some bald eagles may steal ducks from hunters or scavenge in garbage dumps.

Behavior

Territoriality- During the nesting period, breeding bald eagles occupy and defend territories (Mahaffy and Frenzel, 1987). A territory includes the active nest and may include one or more inactive nests, which the eagles may maintain, even when not in use for nesting in a given year

(Hansen et al., 1984). They maintain the same territory year after year, using the same nest or an alternate nest within the same territory (Steidl et al., 1997).

The defended territory contains not only the nest trees, but also favored perches and roost(s). Territories have been reported to range from 0.2–4.2 km^2 (Garrett et al., 1993), but size varies according to site and other parameters (Stalmaster et al., 1985). The territory is within a larger home range. Bald eagles, unlike many other birds, do not necessarily use a territory to monopolize food, but commonly range out of their territory to obtain food communally at a site where it is abundant (Stalmaster, 1987).

In any given year, not all territories will be occupied, and not all occupants will attempt to reproduce (Stalmaster, 1987). During the non-breeding season, or if not breeding, bald eagles generally do not defend territories (Armstrong, 2010), although a pair may remain close to their nest or return to their territory regularly over the winter (Gende, 2010). Information is not currently available on characteristics of bald eagle territories (e.g., size, use patterns, average number of nests, variability according to habitat type, etc.) in the Nushagak or Kvichak watersheds.

Flocking- When a food resource is concentrated, bald eagles will often forage in large flocks (Stalmaster, 1987). This is true not only for scavenging and stealing, as can occur when carrion is present, but also for hunting, when there are large aggregations of forage fish like eulachon or sandlance (Stalmaster, 1987; Stalmaster and Gessaman, 1984; Willson and Armstrong, 1998).

In the winter, when food availability is limited (e.g., by iced-over rivers or limited daylight), bald eagles aggregate in large flocks and become very aggressive, often pirating food from other birds. An available food source will initially draw bald eagles to a site, and the presence of large numbers of bald eagles will attract additional birds.

At night, non-breeding and wintering bald eagles may congregate in communal roost areas (Hansen et al., 1980). The same roost areas are used for several years. Roosts are often in locations that are protected from the wind by vegetation or terrain, providing a favorable thermal environment. The use of these protected sites helps minimize the energy stress encountered by wintering birds. Communal roosting may also assist bald eagles in finding food. The use of communal roosts is poorly documented in Alaska, however (USFWS, 2009a).

Migration and Local Movements- The extent to which bald eagles are migratory or non-migratory varies with breeding site and the severity of its climate (particularly in winter), whether the individual is adult or sub-adult, and year-round food availability (Buehler, 2000). Bald eagles breeding in coastal Alaska typically remain in the vicinity of their nest sites throughout the year. For example, the southeast Alaska adult population is mostly non-migratory, remaining in its rainforest habitat year-round (Sidle et al., 1986). Adults in Aleutian Island populations are generally resident as well (Sherrod et al., 1976). Wintering grounds for migratory Alaska bald eagles are not well understood, but it is suspected that Interior bald eagles winter in the Intermountain West and Pacific Northwest (Ritchie and Ambrose, 1996).

Diurnal and tidal cycles affect the daily activity patterns of fish, as well as enhancing or inhibiting hunting conditions for bald eagles (Hansen et al., 1986).Variations in these daily patterns lead to local movements of bald eagles.

Even though the population of bald eagles in southeast Alaska is non-migratory, individuals will leave their territories to visit foraging areas for several days at a time (Kralovec, 1994). Southeast pairs also return to their breeding territory periodically over the course of the winter.

Local movement patterns, the extent of over-wintering and migration, and how each may vary with age, food availability, or other factors are poorly understood for the Bristol Bay watershed. It is known that at least some adults and sub-adults over-winter in Bristol Bay (Wright, 2010).

Interspecies Interactions

Prey availability has a strong influence on bald eagle reproduction, habitat use and territorial behavior in Alaska. The studies of Hansen et al. (1984) suggest that salmon availability in spring is tightly correlated with if and when adult bald eagles will lay eggs in a given year, although this has not been studied in the Bristol Bay watershed. Bald eagles preferentially select nest sites near stable food supplies (e.g., salmon in the Chilkat Valley). These studies also indicate that food (salmon) availability during the nesting period regulates the survival rate of offspring. Hansen et al. (1984) further determined that, while breeding adults commonly defended feeding territories, they did not do so when salmon became overabundant. Fall and winter habitat use is often correlated with salmon availability, too. Hansen et al. (1984) clearly demonstrated this in the Chilkat Valley and is likely true in Bristol Bay as well.

Bald eagles defend vulnerable young against predators (Stinson et al., 2001). Otherwise they do not tend to be as aggressive with other species as they are with other eagles, with which antagonistic interactions regularly occur during feeding and territory defense. One exception is osprey (*Pandion haliaetus*), which bald eagles commonly keep from nesting nearby (Stalmaster, 1987), although this behavior has not been investigated in the Bristol Bay area. Great horned owls (*Bubo virginianus*), which nest earlier than bald eagles, and osprey, which nest later, each may occupy bald eagle nests in southwest Alaska (Savage, personal communication). Bald eagles steal and scavenge food from a variety of bird and wildlife species, including river otter (*Lutra canadensis*) and sea otter and many others (Stalmaster, 1987).

Breeding, Productivity, and Mortality

Breeding- As with other birds, the timing of bald eagle nesting varies by latitude; in Alaska it begins with courtship and nest building as early as February and ends when the young fledge in late August to early September. In the Bristol Bay watershed, initiation may not be until mid- to late March (Savage, personal communication). The young are attended by the adults near the nest for several weeks after fledging (Buehler, 2000). A pair's territory frequently contains more than one nest (Haines and Pollock, 1998), although a pair uses only one nest in a given breeding year and does not necessarily breed every year (Hansen and Hodges, 1985). The territory (and pair bond) is usually maintained for life (Jenkins and Jackman, 1993).

Whether or not bald eagle pairs breed in a given year and how early they may initiate nesting in a given year appear to be related to food availability (Hansen, 1987), particularly in spring

(Hansen et al., 1984). These studies suggest that there may be a natural long-term population cycle, at least in southeast Alaska's Chilkat Valley, resulting from a saturated breeding habitat and surplus of non-breeders, who then compete for food and cause productivity to decline. The decline may result in less recruitment into the non-breeding population, less competition, and ultimately increased productivity. Annual occupancy rates at known nest sites within Togiak NWR varied from 45 to 88% between 1986 and 2006 (Swaim, personal communication). The lowest occupancy rate occurred in 2006, when spring break-up was particularly late. Occupancy rates, relationships with food availability and seasonal variability, and other details of bald eagle breeding are not well understood for the Nushagak and Kvichak watersheds.

Even well-established nesting bald eagles are highly sensitive to disturbance, particularly during the phases of early courtship and territory establishment, incubation, and the first two weeks after hatching (Buehler, 2000). As with many birds, a constant level of nest attendance is required during incubation and brooding. Bald eagles in newly established territories are highly sensitive to disturbance and prone to abandon nest sites during the courtship and nest-building stage (Gende et al., 1998). Occasionally, a pair will establish and maintain a territory in urban or semi-urban areas where some, usually predictable level of, disturbance already occurs (Zwiefelhofer, personal communication).

Females are larger than males (Buehler, 2000). Both sexes incubate eggs, brood young, and deliver prey to chicks, sharing the duties more than many other raptor species, although females still undertake these tasks a greater percentage of the time than males (Cain, 1985).

Productivity and Survivorship- Productivity varies among sites according to prey abundance and availability, habitat quality, weather, breeding-season length, nesting density, and human disturbance (Gende et al., 1997; Hansen, 1987; Savage, 1997; Steidl et al., 1997). Measures of annual productivity include number and percentage of occupied nests, successful nests, and young produced. Some local information about bald eagle productivity in the Bristol Bay area can be gleaned from National Park Service nest surveys in Lake Clark and Katmai NPPs. Average nest success (percentage of occupied nests that produced at least one young) for interior LCNPP was about 55% between 1992 and 2009, falling to 48% in 2010 (Mangipane, 2010). Nest success for the Naknek Lake and major associated drainage areas of Katmai NPP varied from 31 to 65% in the years 1992 through 1997, although the sample size was relatively small (Savage, 1997).

Dates vary, but generally egg-laying begins in mid- to late April in Alaska (Savage, personal communication; Swaim, personal communication). Clutch sizes range from one to three eggs. Successful pairs usually raise one or two young, or rarely, three per nest (Table 9). Bald eaglets make their first unsteady flights about 10 to 12 weeks after hatching, and fledge (leave their nests) within a few days after that first flight. The time between egg-laying and fledging is approximately four months. However, young birds usually remain in the vicinity of the nest for several weeks after fledging and depend on their parents for food until they disperse from the nesting territory approximately six weeks later. The entire breeding cycle, from initial activity at a nest through the period of fledgling dependency, is about six months (Buehler, 2000).

Numbers of young produced overall in the Nushagak and Kvichak watersheds is unknown. Annually, Alaska bald eagles may produce roughly 4,200 fledglings, although that figure varies considerably according to site and year (Schempf, 1989). In Alaska, both inter-annual and site-specific variability in productivity can be significant (Schempf, 1989) and neither has been comprehensively studied for the Nushagak and Kvichak watersheds. Productivity appears to be most commonly related to site-specific habitat features and prey (fish) availability in early spring during egg-laying and incubation (Anthony, 2001; Gende et al., 1997; Steidl et al., 1997). Availability of fish increases survivorship of bald eagle offspring, and therefore can cause bald eagle productivity to fluctuate widely (Hansen et al., 1984). Variability in food availability appears to be the cause of variability in fledging rates in southeast Alaska (Hansen, 1987). Productivity can be affected by human disturbance, as well (Fraser and Anthony, 2010; Stalmaster, 1987).

Mortality- Full-grown bald eagles have few natural enemies, and the most frequently reported causes of premature adult bald eagle mortality are human-related (Franson et al., 1995; Harmata et al., 1999; Stalmaster, 1987). Shooting, electrocution, trapping, and collisions cause about two-thirds of reported deaths. Bald eagles also die from ingesting pesticides and contaminated carrion used for predator control. Historically, bald eagles experience decreased reproduction and survival from both intentional and unintentional effects of a wide range of pesticides and environmental contaminants (Buehler, 2000). Poisoning from a wide variety of sources accounted for 16% of all deaths in bald eagles necropsied between 1963 and 1994 at the National Wildlife Health Center (Franson et al., 1995).

Top-level predators, such as bald eagles, are believed to be especially vulnerable to many contaminants and can be used as sentinel species for contaminated areas (Holl and Cairns, 1995; Welch, 1994). Eggs from bald eagles in the Aleutian Islands, for example, contained elevated levels of organochlorine pesticides, but concentrations of these contaminants and mercury were significantly higher in eggs from Kiska Island than in eggs from the other islands (Anthony et al., 1999). In contrast, polychlorinated biphenyl (PCB) concentrations were higher in eggs from Adak, Amchitka, and Kiska islands than in those from Tanaga Island. The most likely source of these contaminants in bald eagles was their diets, which were spatially and temporally variable. A similar study found that contaminant concentrations in Aleutian bald eagle eggs were influenced more by point sources of contaminants and geographic location than by the trophic status of eagles among the different islands (Anthony et al., 2007).

Mean cadmium, chromium, mercury, and selenium concentrations in bald eagle tissues from Adak Island were consistent with levels observed in other avian studies and were below toxic thresholds (Stout and Trust, 2002). However, elevated concentrations of chromium and mercury in some individuals may warrant concern. Furthermore, although mean PCB and *p,p'*-dichlorodiphenyldichloroethylene (DDE) concentrations were below acute toxic thresholds, they were surprisingly high, given Adak Island's remote location.

Table 10. Reported survival of bald eagle nestlings in Alaska.

Site and year(s)	Average number of young raised to near [a] fledging per successful nest	Source
Interior LCNPP (1992–2011)	1.00–1.87 [b]	Witter and Mangipane (2011, in preparation)
Coastal LCNPP(1992–2011)	1.09–1.82 [b]	Witter and Mangipane (2011, in preparation)
Pacific Coast of the Alaska Peninsula (1989–1995)	1.55–1.71	(Dewhurst, 1996)
Port Moller (1976)	1.90 [b]	R. Gill, unpublished data reported in Wright (2010)
Togiak NWR (1986–1988)	0.95–1.90	L Hotchkiss and D. Campbell, unpublished data, as reported in Wright (2010)
Togiak NWR (1986–2006)	1.33–2.00 [b]	M. Swaim, personal communication
Togiak NWR (2006)	1.72	(MacDonald, 2006)
Togiak NWR (1999–2005)	1.62	(MacDonald, 2006)
Katmai NPP (1976–1979)	1.2–1.8 [b]	W. Toyer, unpublished data reported in Wright (2010)
Katmai NPP (1992-1993)	1.45–1.67	(Savage, 1993)
Kodiak NWR (1963 and 2002)	1.66	(Zwiefelhofer, 2007)
Petersburg area (1967–1969)	1.50–1.65	(Corr, 1974)
Gulkana River (1989–1994)	1.29–1.65	(Steidl et al., 1997)
Copper River (1989–1994)	1.34–1.64	(Steidl et al., 1997)
Chilkat Valley (1979–1983)	1.32	(Hansen et al., 1984)
Prince of Wales Island (1991–1993)	1.10	(Anthony, 2001)

[a] Nests are normally surveyed just before fledging to assess success and it is assumed that nests are successful if young are observed. This is because once young fledge and leave the nest it is impossible to determine if they survived. [b] Successful nests with three young have been reported in Lake Clark and Katmai NPPs and Port Moller (L. Witter, personal communication, and as reported in Wright [2010]). Also, 3% of nests on Togiak NWR between 1986 and 2006 had three young (M. Swaim, personal communication).

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Non-human causes of mortality include starvation, fights with other bald eagles, and incidental diseases and infections (Stalmaster, 1987). When food is limited, mortality rates are probably higher among sub-adult than adult bald eagles (Stalmaster and Gessaman, 1984). Other causes of mortality include loss of nests (eggs and nestlings) to spring storms, parental desertion or death, and predation by gulls, black bears (*Ursus americanus*), and other predators (Stalmaster, 1987). Although eggs tend to have a higher mortality rate than nestlings, nestlings also kill each other in fights, die from starvation when more aggressive nest mates receive the majority of feedings from the parent, and fall prematurely from nest trees.

Population, Distribution, and Abundance

Bald eagles are one of the most abundant raptors in Alaska, with a population estimated at >58,000 (Hodges, 2011). Most Alaskan bald eagles occur in the vicinity of the southern coast (from Dixon Entrance to Bristol Bay) and secondarily along interior rivers and lakes (Schempf, 1989). An estimated 2,775 adult bald eagles were present along the Alaska Peninsula Gulf Coast in 2005 (Savage and Hodges, 2006).

Surveys of nests and calculations of nest densities and occupancy rates are commonly conducted to contribute to bald eagle population information, although nesting rates have considerable temporal and spatial variability. Nesting density is considered to be generally correlated with food availability (Dzus and Gerrard, 1993), although density of breeding bald eagles in Saskatchewan was found to be correlated with mean April temperatures (Leighton et al., 1979). Densities of nests in inland river areas of southeast Alaska are highly variable among sites and years. This may be correlated with food abundance and weather conditions (Hodges, 1979). Nests in the Susitna watershed, though, are thought to be more uniformly distributed (Ritchie and Ambrose, 1996). For Interior Alaska populations, Ritchie and Ambrose (1996) surmise that densities are greatest in areas adjacent to abundant coastal populations and where weather is somewhat milder and prey more seasonally accessible and diverse.

Bald eagle densities have been extensively studied in southeast Alaska. A review of several nesting density investigations in various southeast Alaska locations revealed densities ranging from 0.33 to 0.50 (perhaps greater on Admiralty Island) active nests per kilometer of coastline and 0.25 to 0.38 active nests per river kilometer (Hansen et al., 1984; Hodges, 1979; Robards and King, 1966). There were 0.01 to 0.08 active nests per river kilometer at an Interior location (Gulkana River) (Byrne et al., 1983). Population and nesting density is also high on Kodiak NWR, where almost 1,000 nests were located within an area of about 8,000 square kilometers in 2002 (Zwiefelhofer, 2007).

A comprehensive survey has not been published for bald eagles or their nests in the Bristol Bay watershed. The data that we do have appears to indicate that nest density may be almost as high in portions of the region as anywhere outside of the highest known densities in southeast Alaska and Kodiak. The USFWS Bald Eagle Nest Database has accumulated approximately 230 nest records for the study area (Table 10). Approximately one-quarter (61) of those records, however, are from the 1970s and 1980s, and those nests may not persist on the landscape. The remaining 169 records were collected between 2003 and 2006. In 2006, a fixed-wing survey of adult bald eagles was conducted by the USFWS along main-stem portions of some Alaskan rivers. During that survey, 50 bald eagle nests were incidentally recorded along portions of the Nushagak,

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Mulchatna, and Kvichak Rivers. Of those 50, approximately one-half (24), were identified as active. Database records for 2004 and 2005 are from a project contractor survey (not flown for the USFWS Database) that was conducted along the north side of Lake Iliamna. The 2004 and 2005 surveys recorded 75 total nests in this area (Lewis, personal communication). This appears to be a relatively high nesting density, although we do not know which or how many of those nests were active, nor therefore, the density of active territories in this area. Data from 2003 are for only three nests, one active and one empty nest in the lower Nushagak drainage and one of unknown status on an islet off the north shore of Iliamna Lake.

Table 11. Summary of surveys for bald eagle nests in the Bristol Bay study area.

Survey	Survey dates and results	
USFWS bald eagle nest surveys (recorded in USFWS bald eagle nest database)	1970–1990 61 nest records	2003–2006 169 nest records
Nushagak and Mulchatna Rivers survey by USFWS	2006 50 nest records (24 active)	
North side of Lake Iliamna survey by contractor	2004–2005 75 nest records	

Regarding numbers of individual bald eagles observed, some site-specific surveys have been conducted in portions of southwest Alaska. For example, summer activity surveys for Katmai NPP identified between 50 and 87 individuals in the Naknek Lake drainage between 1991 and 1997 (Savage, 1997). Systematic efforts have not been made to identify fall bald eagle congregation sites in the Bristol Bay area (Wright, 2010). Such sites are known to exist in surrounding areas (e.g., Port Moller, Savonoski River), however, and are believed to be related to late-spawning sockeye salmon, fall runs of coho salmon, and fall-staging waterfowl. While bald eagle densities are undeniably greatest overall in southeast Alaska, salmon also appear to be a major driving force for the Bristol Bay watershed population of bald eagles, so some comparisons may be inferred. In the Chilkat Valley, fall and winter bald eagle densities in habitats adjacent to foraging areas may be ten times those of the same habitats (e.g., gravel bars, cottonwood stands) located distant from food sources (Hansen et al., 1984).

Human Use

Historically, bald eagles have been important to Native Americans and continue to be so at present. Bald eagle parts have been of particular importance for rituals and many other spiritually related uses (Stalmaster, 1987). The Bald and Golden Eagle Protection Act exempts Native Americans from the prohibition against purposeful take, although a permit is required.

Other humans have not used bald eagles historically for any significant intrinsic purpose. Humans, however, are the greatest source of the bird's mortality, both directly and indirectly. At least 128,000 birds, and probably many more, were taken during the bounty years (1917 to 1952) in Alaska. Bald (and golden) eagles are now protected by law in the United States, with only a

minimal number of permits for indirect take (incidental to an otherwise lawful activity) allowed. Take is authorized only when it is consistent with the goal of maintaining stable or increasing bald eagle populations.

Despite legal protection, illegal direct take still occurs, most commonly when bald eagles are shot, trapped, or poisoned based on a belief that the birds prey on human-valued resources. Unpermitted indirect take is probably the greatest source of bald eagle mortality today. Leading causes of indirect take include pesticides, entanglement in fishing or trapping gear, collisions with power lines or buildings, ingestion of poisoned prey, plastics or lead shot, and disturbance or loss of nesting habitat (Buehler, 2000).

SHOREBIRDS

Introduction

Shorebirds are a diverse group, with members occurring on every continent and in all habitats ranging from sea level to the highest mountains. They generally are associated with water, particularly intertidal and estuarine environments, and thus are fairly visible to humans. Due to their broad geographic distributions, their seasonal migrations are remarkable, regularly spanning continents and frequently hemispheres. Several species engage in long, nonstop flight, but most rely on a series of sites where they stop to "refuel" for subsequent legs of their migrations. Alaska intertidal areas, particularly Bristol Bay estuaries, serve two functions in this regard. First, during late summer through autumn, the majority of the shorebird population that nests in western Alaska moves to the benthic-rich intertidal communities of Bristol Bay, where ample food supports them while they complete their molt and fatten for autumn migrations. Winter destinations include sites throughout the Americas, the Central Pacific, and Australasia. Secondly, during spring, hundreds of thousands of shorebirds that staged on the Copper River Delta and estuaries of Cook Inlet migrate to their western Alaska breeding grounds, through a broad lowland corridor (the Lake Iliamna corridor) at the base of the Alaska Peninsula, linking Kamishak Bay in lower Cook Inlet to upper Bristol Bay. In most years, the migration through this corridor is direct, but in years with late spring or adverse weather conditions, birds stop in large numbers at Bristol Bay estuaries until conditions improve farther west (Gibson, 1967; Gill and Handel, 1981; Gill and Tibbitts, 1999). Two major estuaries in the area, Nushagak and Kvichak bays, have been recognized as Western Hemisphere Shorebird Reserve Network sites (Western Hemisphere Shorebird Reserve Network, 2011).

Over 70% of the shorebird species or subspecies (30 of 41) that regularly occur in Alaska each year (Alaska Shorebird Group, 2008) can be found in the Bristol Bay watershed; 21 of these 30 (70%) regularly nest there (Table 12). Shorebird populations worldwide are showing steady declines (Stroud et al., 2006), with causes most often attributed to loss or alteration of habitats and environmental contamination. Fourteen species that regularly occur in the Bristol Bay watershed have been ranked by the Alaska Shorebird Working Group (2008) as being of high conservation concern.

The Bristol Bay region has had a long history of studies that reported in part on shorebirds. Several of these studies date to the late 19th and early 20th centuries, but few shorebird-specific studies emanated from this region until the initiation of the Outer Continental Shelf Environmental Assessment Program (OCSEAP) in coastal Alaska in the early 1970s (Arneson, 1978; Gill et al., 1977; Gill et al., 1978). At that time, there was also increased interest in declining populations of waterfowl throughout Alaska and considerable information on shorebirds was collected in conjunction with waterfowl studies, such as annual spring and fall emperor goose aerial surveys (Mallek and Dau, 2011). There have also been multiple studies detailing shorebird activities during the breeding season and migration in the adjacent Kilbuck and Ahklun Mountains and coastal areas from Kuskokwim Bay to Togiak (Petersen et al., 1991). Breeding activities of several shorebird species in the Iliamna Lake area have also been reviewed (Williamson and Peyton, 1962).

Table 12. Shorebirds found in the Bristol Bay Watershed.

Species	Scientific name	Breeding[1]	Current Trend[2]	Conservation Priority[3]
Black-bellied Plover	*Pluvialis squatarola*	Yes	Declining	3
American Golden-Plover	*Pluvialis dominica*	Yes	Declining	4
Pacific Golden-Plover	*Pluvialis fulva*	Yes	Declining	3
Semipalmated Plover	*Charadrius semipalmatus*	Yes	Stationary	2
Spotted Sandpiper	*Actitis macularius*	Yes	Stationary	2
Wandering Tattler	*Tringa incana*	Yes	Stationary	3
Greater Yellowlegs	*Tringa melanoleuca*	Yes	Stationary	3
Lesser Yellowlegs	*Tringa flavipes*	Yes	Declining	4
Whimbrel	*Numenius phaeopus*	Yes	Declining?	4
Bristle-thighed Curlew	*Numenius tahitiensis*		Stationary	5
Hudsonian Godwit	*Limosa haemastica*	Yes	Stationary	4
Bar-tailed Godwit	*Limosa lapponica*	Yes	Declining	4
Marbled Godwit	*Limosa fedoa*		Unknown	4
Ruddy Turnstone	*Arenaria interpres*		Unknown	3
Black Turnstone	*Arenaria melanocephala*	Yes	Stationary	4
Surfbird	*Aphriza virgata*	Yes	Declining	4
Red Knot	*Calidris canutus*		Declining	4
Sanderling	*Calidris alba*		Declining	4
Semipalmated Sandpiper	*Calidris pusilla*		Declining	3
Western Sandpiper	*Calidris mauri*	Yes	Declining?	4
Least Sandpiper	*Calidris minutilla*	Yes	Declining	3
Baird's Sandpiper	*Calidris bairdii*		Stationary	2
Pectoral Sandpiper	*Calidris melanotos*	Yes	Declining	2
Sharp-tailed Sandpiper	*Calidris acuminata*		Stationary	2
Rock Sandpiper	*Calidris ptilocnemis*	Yes	Stationary	4 or t 3
Dunlin	*Calidris alpina*	Yes	Declining	4
Short-billed Dowitcher	*Limnodromus griseus*	Yes	Declining	4
Long-billed Dowitcher	*Limnodromus scolopaceus*		Stationary	3
Wilson's Snipe	*Gallinago delicata*	Yes	Declining	3
Red-necked Phalarope	*Phalaropus lobatus*	Yes	Declining	3

[1] Breeding status of "Yes" requires a record of breeding evidence (nest, eggs, or recently fledged young on or within 150 km of the Bristol Bay Watershed.
[2] Current trends were reproduced from Morrison et al. 2006, Table 1: Estimates, Current trend.
[3] Conservation Status scores were reproduced from Alaska Shorebird Plan 2008, Table 2, Conservation Category. Species in Categories 4-5 are of high concern and in category 2-3 are of low to moderate concern.

In more recent years avian surveys have been conducted by the National Park Service in Lake Clark and Katmai NPPs (montane surveys including the upper Nushagak and Kvichak drainages)

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(Ruthrauff et al., 2007); by the USFWS (targeting lowland areas of the northern Alaska Peninsula) (Savage and Tibbitts, In prep); by the Pacific Shorebird Migration Project (including satellite tracking of godwits (*Limosa* spp.), bristle-thighed curlew (*Numenius tahitiensis*), and whimbrel (*N. phaeopus*)) (Gill et al., 2009); using color banding (whimbrels) (Tibbetts, personal communication); and using radio tracking and attachment of geo-locators (plovers (*Charadriidae*)) (Johnson et al., 2004; Johnson et al., 2001; Johnson et al., 2011; Johnson et al., 2008). These surveys have provided additional understanding of the importance of this region to various stages of shorebird life history. A deficiency in information for upper Bristol Bay during the early spring still exists, but information for nearby Egegik (Fernandez et al., 2010) and Nanvak bays (Fernandez et al., 2010; Petersen et al., 1991) are relevant to this characterization. The paucity of information for the early spring stems in part from the winter-like conditions that frequently persist in the Bristol Bay region until early May, affecting, if not the birds' use of the area, then at least the ability of biologists to access it.

The Bristol Bay/Alaska Peninsula lagoon system, of which the Nushagak and Kvichak River deltas are part, is one of the most important migratory shorebird stop-over areas in the state. Only the Copper River Delta and the Yukon-Kuskokwim Delta are likely more important (Gill and Handel, 1990; Isleib and Kessel, 1973; Senner, 1979). The entire set of lagoons supports thousands of individuals, representing numerous shorebird species, that undertake post-breeding migrations to the Pacific coast of North America and across the Pacific Ocean to Australia, Southeastern Asia, and Oceania. For species that migrate directly across the ocean to Hawaii or other South Pacific islands (e.g. bar-tailed godwit (*Limosa lapponica*), ruddy turnstone (*Arenaria interpres*)), these lagoons provide the last stopover before their long overwater flights. Western sandpiper (*Calidris mauri*), dunlin (*C. alpina*), and long-billed dowitcher (*Limnodromus scolopaceus*) use the peninsula's lagoons to replenish energy reserves before departing non-stop for British Columbia and points south. The Bristol Bay lagoons are also used by shorebirds as they migrate north in spring, providing an essential refueling location that enables species not only to succeed in reaching their breeding grounds, but also to begin breeding shortly thereafter. The relative importance of each lagoon/delta, including the deltas of the Bristol Bay region, is likely to vary annually and by species, and the loss of any one site might have a devastating effect on a species' ability to successfully migrate and consequently might add another factor to already declining populations.

Habitat

The geomorphology of upper Bristol Bay is shaped by the interaction between the shallow basin of the Bay and the twice-daily tidal fluctuation in excess of 10 m. These features interact with the numerous river deltas, including the Nushagak, Kvichak, and Naknek, to form an expansive intertidal zone dominated by unvegetated sand and mudflats. The intertidal zone also includes vegetated substrate at Nushagak Bay. These intertidal areas, the Bristol Bay estuary itself, and other nearby river mouths with extensive mudflats along the Alaska Peninsula characterize the estuarine portions of the region. Approximately 530 km^2 of intertidal habitat is found at Kvichak Bay and 400 km^2 at Nushagak Bay (Gill et al.; Western Hemisphere Shorebird Reserve Network, 2011). In winter, substantial shore ice forms along the coast and sea ice moves through the area with the tides. The supralittoral (splash) zone varies from gradually sloping unvegetated or sparsely vegetated shore, to sand and morainal bluffs up to 20 m in height. Beyond the shore zone, the region is characterized by a mosaic of wetland and tundra habitats, punctuated with low

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and tall shrub communities, located primarily along drainages. At higher elevations are spruce, mixed spruce, birch or cottonwood forests that give way to ericaceous dwarf shrub or sparsely vegetated substrates in the alpine zone.

Shorebirds inhabit the Bristol Bay watershed primarily during two phases of their annual life cycle: migration and breeding season. During each phase they make use of geographically distinct parts of the watershed. Shorebirds use the expansive intertidal and adjacent supralittoral areas during both spring and fall migrations. In spring, the mouths of major rivers including the Naknek, Kvichak and Nushagak, are often the first areas to become ice-free, and provide critical feeding habitat in the littoral zone (Gill and Handel, 1981). Shorebirds actively forage in the intertidal zone, often moving toward the declining water level as the tide drops. During high tide and at night, birds move into the adjacent supralittoral zone to continue foraging or to roost. Although information for these specific bays is sparse for the spring period, we can make inference from observations in nearby areas. Beginning in late April through mid-May, the predominant species to use the Bristol Bay region (western tip of Unimak Island north to Cape Newenham, as defined in Gill and Handel, 1981) include: bar-tailed godwit (several thousand), western sandpiper (a few thousand), rock sandpiper (*C. ptilocnemis*; a few thousand), dunlin (a few thousand), black-bellied plover (*Pluvialis squatarola*; hundreds to thousands), Pacific golden-plover (*P. fulva*; several hundred), black turnstone (*Arenaria melanocephala*; several hundred), red-necked phalarope (*Phalaropus lobatus*; several hundred), Hudsonian godwit (*Limosa haemastica*; a few hundred), and short-billed dowitcher (*Limnodromus griseus*; a few hundred)(Gill and Handel, 1981). Other species are found in lesser numbers.

Beginning in mid- to late June, shorebirds return to Bristol Bay in larger numbers and remain for protracted periods along the intertidal zone. This general shift between terrestrial habitats and the littoral zone is observed throughout the region (Gill and Handel, 1981; Gill and Handel, 1990; Gill et al., 1977; Gill et al., 1978) and Alaska (Connors, 1978; Taylor et al., 2011). Shorebirds also make use of the supralittoral zone and terrestrial habitats near the coast during high tides and at night for feeding and for roosting (Gill and Handel, 1981; Gill et al., 1981). Initially, the primary birds present in the region are those nesting locally, but as the season progresses, populations swell with birds moving into the region from nesting areas in western and northern Alaska and as far away as eastern Russia (Gill et al., 1994). By early August it is not uncommon to find hundreds of thousands of shorebirds on intertidal areas of upper Bristol Bay. Species composition and abundance in fall is similar to the spring migration except for additional species and increased numbers: bar-tailed godwit (thousands to ten thousands), dunlin (several ten thousands), red-necked phalarope (several ten thousands), and red phalarope (several ten thousands), western sandpiper (a few ten thousands), rock sandpiper (a few ten thousands), short-billed dowitcher (a few ten thousands), black-bellied plover (a few thousands), Pacific golden-plover (a few thousands), whimbrel (a few thousands), ruddy turnstones (a few thousands), black turnstones (a few thousands), sanderlings (a few thousands), long-billed dowitcher (a few thousands), greater yellowlegs (hundreds to thousands), semipalmated plover (several hundreds), Hudsonian godwit (a few hundreds) (Gill and Handel, 1981; MacDonald, 2000; MacDonald and Wachtel, 1999). Populations awaiting storms to help carry them to Australasia and the west coast of North America may extend their period of use into October (e.g., dunlin) (Gill et al., 1978) or early November (e.g., bar-tailed godwit) (Gill et al., 2009).

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Shorebirds breeding in the Bristol Bay watershed use different habitats in the terrestrial areas of the watershed, from the supralittoral zone (Gill and Handel, 1981; Gill et al., 1981) to elevations of 1,300 m (Ruthrauff et al., 2007), based on their species' preferences. Many species (e.g., greater yellowlegs, dunlin, Wilson's snipe (*Gallinago delicata*), and short-billed dowitcher) prefer mesic to wet herbaceous vegetation, while many of the plovers or montane breeders (e.g., American golden-plover (*Pluvialis dominica*), semipalmated plover, surfbird (*Aphriza virgata*), rock sandpiper), prefer dwarf shrub/lichen vegetation or even barren areas for nest sites. Several species are highly dependent on lake or river shores (e.g., spotted sandpiper (*Actitis macularius*), wandering tattler (*Tringa incana*)) (Petersen et al., 1991). A few species (semipalmated plover, marbled godwit (*Limosa fedoa*), black turnstone, dunlin, and short-billed dowitcher) prefer the coastal fringe (Gill and Handel, 1981; Gill et al., 2004). All of these shorebirds may feed in marine intertidal zones during breeding, depending on their proximity or their preference for feeding in these environments.

Food Habits

The shorebird group derives its name from the fact that many species spend migration, and often winter, associated with shore environments. In many cases, these are marine shores. Food is likely the most important factor controlling the movements of shorebirds throughout the Bristol Bay region. Use of Nushagak and Kvichak Bays during shorebird migration is undisputed. In the spring, shorebirds need to acquire critical food resources, not only to fuel their migration, but also, for some species, to assure that they arrive on the breeding grounds with sufficient reserves to initiate nesting and egg production (Klaassen et al., 2006; Yohannes et al., 2010). Beginning mid-summer and continuing into early autumn, shorebirds in Alaska must again find food-rich areas to support the process of partial or complete molt (a few species) and to fuel extended migration (all but a few species). Indeed, some of the longest migrations known to birds involve shorebird species (bar-tailed godwit) that use Bristol Bay intertidal areas in autumn (Battley et al., 2011; Gill et al., 2009). Such flights are possible not only due to the extreme abundance of intertidal invertebrates (polychaetes, crustaceans, gastropods, and bivalves) in the region, but also because the adjacent uplands are usually rich in fruits of ericaceous plants or tubers that birds like plovers, whimbrels, and godwits, regularly feed on (Elphick and Klima, 2002; Johnson and Connors, 1996; Paulson, 1995; Skeel and Mallory, 1996). For species like bar-tailed godwit and sharp-tailed sandpiper, individuals can gain up to 6% of their lean body mass per day while feeding prior to migration (Gill et al., 2005; Lindstrom et al., 2011). Other species acquire their fuel at a different trophic level. Rock sandpiper, for example, often eat the gonads of tide-stranded jellyfish medusae, while species like whimbrel, Hudsonian godwit, and black and ruddy turnstones feed on herring roe, carrion and salmon eggs (Elphick and Tibbitts, 1998; Gill et al., 2002; Handel and Gill, 2001; Nettleship, 2000; Norton et al., 1990). During the breeding season terrestrial and freshwater environments provide the bulk of the food sources and a wide variety of animal and vegetable resources are consumed. Most shorebird species make use of terrestrial invertebrates or their larvae or eggs, and many make use of freshwater invertebrates; small fish may be consumed by yellowlegs (Elphick and Tibbitts, 1998) and phalaropes (Rubega et al., 2000). Detailed summaries for each species are found in *The Birds of North America* (Cornell Lab of Ornithology, 2011).

Shorebirds play a role in distributing MDNs into the terrestrial system, especially during the migratory period, but this has not been quantified. They frequently feed in the intertidal zone, but

roost in the terrestrial zone, where they frequently deposit their waste. In addition, they are prey items for many larger predators that subsequently cycle the nutrients into the terrestrial system.

Behavior (Movements)

Shorebirds move at multiple temporal and spatial scales that are usually associated with specific phases of their annual cycle, but within each, there can also be movement driven by more random events such as weather and opportunistic feeding. The most obvious movements are associated with migration, a phenomenon that occurs twice a year in most shorebirds. Spring migration in Alaska is an end to a process that began months prior and often continents away and is driven by the pending nesting season and the need for birds to establish territories and produce young. As such, it is characterized as rapid and direct (Gill and Handel, 1981), with little use made of intertidal areas once birds leave penultimate staging sites such as the Copper River Delta (Isleib, 1979; Iverson et al., 1996; Senner, 1979).

Spring conditions in Bristol Bay vary greatly from year to year. Shore bound and riverine ice can vary considerably with regard to magnitude and timing of melt, depending on the severity of the winter, amount of snow cover, and the onset of spring conditions. Currently, no formal measure of shore ice is conducted in this region; however remote sensors such as MODIS (Moderate Resolution Imaging Spectroradiometer) could be used to describe and monitor spring conditions (Spencer, 2006). Informal observations indicate that breakup may begin as early as late March or be delayed until early May. The ice conditions may change within a week or may linger for four to six weeks. Shorebirds make use of the Bristol Bay tidal flats as they become ice-free, typically beginning in mid- to late April and peaking in early May; the length of their stay depends in part on conditions in the nearby breeding grounds or further north on their migratory route.

Spring shorebird surveys are limited for this area and most information comes from surveys targeting other taxa. With that in mind, note that peak numbers for single aerial surveys along the margins of the two bays range from approximately 7,000 to 10,600 small to medium shorebirds (Arneson, 1978; King and Dau, 1992). Arneson (1978) conducted several surveys in one spring and mentions that spring shorebird densities can change dramatically over a short time span. Although spring migration is abbreviated, variation in migration timing by sex is known for some species with males generally arriving earlier (Senner et al., 1981).

Once established on the breeding grounds, most shorebirds exhibit territorial behavior. Movements are driven by the need to defend territories, attract mates, establish and defend nests and young, feeding, and the need to find shelter from weather and predators. Once young fledge, or when nesting attempts fail, many species move to coastal habitats; such movement may be driven by deteriorating food supplies on the nesting grounds or increased availability of food in the littoral habitats (Gill and Handel, 1981).

Shorebirds return to the coastal zone beginning in mid-June, with some remaining until early November. Summer and fall food resources in Bristol Bay are diverse and abundant, as evidenced by the diversity and numbers of shorebirds, waterfowl and seabirds that are attracted to the area during this time (Gill et al., 1981). A clearly attractive attribute of Bristol Bay is the short distance birds must move between various components of its large system of interconnected mudflats and bays, all containing concentrated food resources. In the context of

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post-breeding shorebird use, Nushagak and Kvichak Bays cannot be separated from the context of the greater Bristol Bay/Alaska Peninsula complex. Rich food resources are in demand, because adult birds are recovering from the energetic stress of breeding and beginning the energy-demanding molt. Ground and aerial surveys conducted in Nushagak Bay (MacDonald, 2000; MacDonald and Wachtel, 1999) and other Alaska Peninsula lagoons (Gill et al., 1977; Gill et al., 1978) provide insight on the seasonality, and duration of use by at least 25 shorebird species. The magnitude of shorebird use has been captured on single-day aerial surveys in the later part of the season; for these two bays, high counts range from 20,000 to 67,000 (Gill and King, 1980; Gill and Sarvis, 1999; Mallek and Dau, 2004). Late summer and fall shorebird use is likely greater than spring, due to the addition of juveniles in the population, longer residence times, different pathways of migrants during different times of the year, or different use patterns of individual species.

The autumn migration is broken into phases based on species, age, sex, and individual breeding success. Species-specific use patterns have been reported for Nelson Lagoon, on the central Alaska Peninsula (Gill and Jorgensen, 1979) and patterns for other species common to the Bristol Bay watershed are reported from studies on the Yukon Delta (Gill and Handel, 1981; Gill and Handel, 1990). In general, black turnstones, western sandpipers and short-billed dowitcher move through the area the earliest; black-bellied plovers arrive later and rock sandpipers, dunlin and sanderlings may arrive at similar or later dates, but remain longer into the fall. Failed breeders move to the coastal zone sooner than successful breeders (Gill et al., 1983; Handel and Dau, 1988). On the Y-K Delta, Gill and Handel (1990) observed three age-based patterns of intertidal use through the late summer. In the most common pattern, demonstrated by western sandpipers, adults arrived first, followed by a period in which adults and juveniles occurred together, and finally juveniles appeared alone. In the second pattern (bar-tailed godwits, dunlin, and rock sandpipers), adults appeared first, followed by a long period of use by both adults and juveniles. The third pattern was demonstrated by plovers, in which only juveniles used the intertidal zone in late summer. In addition, some species demonstrate a sex-specific pattern: female western sandpipers depart before males (Gill and Jorgensen, 1979), but in pectoral sandpipers (*Calidris melanotos*), males depart before females (Pitelka, 1959). The specific migration patterns demonstrated by individual shorebirds, with regard to micro- and macro-habitat use and timing, will become clearer as researchers continue to deploy satellite transmitters and geo-locators.

Interspecies Interactions

Shorebirds act as an intermediate link in the food web between primary producers (berries, seeds, and tubers of plants) /consumers (invertebrates and small fish) and predatory species. Especially during migration, when birds are concentrated, their effect on invertebrate populations in feeding areas can be extensive (Jensen and Kristensen, 1990; Quammen, 1984; Sanchez et al., 2006; Wilson, 1989). The response of the invertebrate prey varies with time of year, substrate, presence of other predators, presence of other prey, and age-related factors of the prey items. Any negative effect on prey abundance is assumedly short-term, however, as these areas are revisited by shorebirds on the next tide and the next season on a daily and annual schedule. Shorebirds may compete intra-specifically or inter-specifically for resources during migration as well, as demonstrated by inter-specific aggressive interactions (Burger et al., 1979).

Shorebird adults, young, and eggs provide food for a wide variety of predatory birds including jaegers, gulls, raptors, owls, corvids, and shrikes. Avian predation has long been hypothesized to be the dominant force in flocking behavior (Lack, 1954); the relationship between the benefits (predator avoidance) and costs (feeding competition) has been explored (Stinson, 1980). Nocturnal avian predators alter shorebird use of feeding and roosting areas (Piersma et al., 2006). The increase in raptor populations following the removal of DDT appears to be altering how much time shorebirds spend in marine intertidal areas; this threat of danger is potentially forcing the birds into a trade-off between good food locations and the potential of being eaten (Ydenberg et al., 2004). In the Bristol Bay ecosystem potential mammalian predators of shorebirds, particularly eggs and chicks, include canids (especially foxes), lynx, weasels (including otter), and some rodents. Shorebirds may play a role as prey in multi-species predator-prey cycles known throughout the Arctic (Underhill et al., 1993).

Direct and indirect interactions between shorebirds and salmon are not well-documented. As mentioned above, some shorebird species are observed to consume dead salmon and salmon eggs, but it is unlikely that shorebirds have an impact on salmon populations. No studies have been conducted to deduce the contribution of salmon to the energetics of shorebird populations; however, the abundance of invertebrates in the intertidal zone is very likely due in part to nutrients from salmon that die on the coast and in the rivers feeding Bristol Bay.

Breeding, Productivity, and Survivorship
Using information from studies in and adjacent to the Bristol Bay watershed, approximately 21 shorebird species are known to breed in this area. Most shorebird species form monogamous pairs, with both sexes defending breeding territories and incubating eggs; however, spotted sandpipers and red-necked phalaropes will engage in polyandry if conditions are favorable. Individuals, and especially males, commonly demonstrate site fidelity to breeding territories. Nesting begins in early to mid-May in the Bristol Bay area (Petersen et al., 1991). Territorial defense is usually strongest during the early part of the breeding season and lessens as chicks hatch (Lanctot et al., 2000). All shorebirds nesting in the Bristol Bay watershed, except solitary sandpiper (*Tringa solitaria*), nest on the ground. Shorebirds usually produce four eggs per clutch. After a nest is depredated or lost due to environmental factors, re-nesting may be attempted in some species, but generally the season is long enough for only one complete nesting cycle (laying, incubation, and brood-rearing). Incubation may take from 18 to 28 days, depending on species; chicks can move to forage in habitats outside of the nesting territories within a few days of hatching. Adults generally brood young for several days or more, until they are thermally independent, and provide defense against predators for two to three weeks. The time from hatch to fledging takes from 17 to 45 days depending on species shorebird. Individual breeding behaviors are discussed at length in the species accounts of the *Birds of North America* (Cornell Lab of Ornithology, 2011).

Alaska is known as a nursery ground for shorebirds; however the Bristol Bay watershed has not been inventoried for breeding shorebird distribution or abundance. Studies from montane areas in adjacent Katmai and Lake Clark NPPs and the Kilbuck and Ahklun Mountains and from lowlands of the northern Alaska Peninsula provide some basis for distribution of breeding species, but cannot be used to estimate breeding densities. For montane areas in Katmai and Lake Clark, the most common species found during May (breeding season) were semipalmated

plover, spotted sandpiper, wandering tattler, greater and lesser (*Tringa flavipes*) yellowlegs, surfbird, least sandpiper (*Calidris minutilla*), and Wilson's snipe (Gill and Sarvis, 1999; Ruthrauff et al., 2007). Ruthrauff et al. (2007) extended the breeding range of several alpine shorebirds (wandering tattler, surfbird, and Baird's sandpiper (*C. bairdii*)) and confirmed these and another three species (black-bellied plover, American golden-plover, Pacific golden-plover), previously only known as migrants, to be breeders in Katmai. In the area west of the Bristol Bay watershed, Petersen et al. (1991) found black-bellied plover, semipalmated plover, spotted sandpiper, greater yellowlegs, western sandpiper, rock sandpiper, dunlin, Wilson's snipe, and red-necked phalarope to be the most common breeding shorebirds. For lowland areas of the northern Alaska Peninsula, the most common shorebird species found during May were greater yellowlegs, least sandpiper, dunlin, short-billed dowitcher, Wilson's snipe, and red-necked phalarope (Savage and Tibbitts, In prep). Other species that breed in the area include whimbrel and Hudsonian godwit (Ruthrauff et al., 2007).

Shorebird productivity, survivorship, and mortality) are affected by many factors that may vary by species, region and annual conditions. Measures of these parameters do not exist specifically for the Bristol Bay watershed and may not exist at all for many species of shorebirds. Productivity may be affected by life history (e.g., age at first reproduction, annual participation in breeding), seasonal abundance of food resources, weather, flooding, predation, and other forms of disturbance. Productivity in birds is measured in various ways, including proportion of eggs hatched, proportion of successful nests, and proportion of young fledged. Shorebird pairs may produce, at most, four chicks per season. Most small and medium-sized birds, including shorebirds, suffer from high mortality during their first weeks and months of life. It is possible that some species may experience complete reproductive failure for a region in some years.

Survival may be affected by food availability, weather and climate, predation, and human-caused mortality (e.g., building strikes, domestic cat predation, and contaminated or degraded habitats); to date, human disturbance, including habitat degradation, is significantly greater along the migratory paths and wintering grounds of most shorebirds, than in the breeding grounds. Once birds reach adult age and have successfully navigated their first migration, survival is generally higher. The U.S. Geological Survey's Bird Banding Lab maintains longevity records for banded birds (USGS Bird Banding Lab, 2011). These records indicate that smaller shorebird species live from 6 to12 years, while some of the medium to larger species have been recorded to live 21 (Pacific golden-plover) to 23 (bristle-thighed curlew) years. The average age of the majority of the population is much lower and is not known for most species of shorebirds.

Population, Subpopulations, and Genetics

Shorebird populations throughout North America are experiencing declines (Alaska Shorebird Group, 2008). Although accurate population data are lacking for most shorebirds, of the 30 regularly occurring shorebird species in the Bristol Bay watershed, 17 are suspected to be declining and 11 are thought to be stationary; there is not enough information to make a determination for two species (Morrison et al., 2006). None of the species using the Bristol Bay watershed are known to be increasing in population.

Two species of shorebirds found in the Bristol Bay watershed may include two or more subspecies, especially during the migratory period. Of the two subspecies of dunlin that breed in

Alaska, it is most likely the *Calidris alpina pacifica* subspecies that migrates through Bristol Bay and not the *C.a. arcticola* subspecies. Subspecies status for this species is still under consideration (Warnock and Gill, 1996). Four to five subspecies of rock sandpiper are found in Alaska and the most likely subspecies to use the Bristol Bay watershed for breeding would be *Calidris ptilocnemis tschuktschorum;* use by *C. p. couesi*, or *C. p. ptilocnemis* during migration may also be possible (Gill et al., 2002).

Human Use and Threats

Shorebirds have been, and continue to be, used as human food. During the latter part of the 19th and early 20th century, shorebirds were harvested commercially, along with waterfowl, for human consumption. The overhunting of shorebirds and waterfowl and the killing of birds for the fashion industry in part led to the development of the Migratory Bird Treaty Act of 1918, and in North America, shorebirds are protected under its provisions. Shorebirds may still be hunted under regulations formulated for each state. In Alaska, Wilson's snipe may be harvested during the fall migratory bird season (1 September to 16 December in the Bristol Bay area). Sixteen shorebird species common to Bristol Bay during some part of their life cycle may be harvested during the Alaska Subsistence Spring/Summer Migratory Bird season (1 April to 14 June and 16 July to 31 August). A harvest survey is conducted in parts of southwest Alaska, with various areas assessed on rotating years; however, participation is voluntary and the reports likely represent minimum harvest levels (Naves, 2011). During the 2009 survey (included the Y-K Delta Region), 1,688 shorebirds and 1,835 shorebird eggs were reported harvested (Naves, 2011). In general, godwits, whimbrels and curlews are targeted, due to their larger size. The value of these shorebirds to the diet and thus economy of Native Alaskans, especially in western Alaska, should not be underestimated.

Non-consumptive uses of shorebirds mostly include shorebird-viewing and tourism associated with that activity. Other areas of Alaska such as Kachemak Bay, the Copper River Delta, and Cordova are developing this industry and depend on birds that will pass through the Bristol Bay watershed. There have been some initial attempts (http://www.visitbristolbay.com/visitor-guide/wildlife.html) to develop the birding tourist industry in the Bristol Bay area.

LANDBIRDS

Introduction

Approximately 80 species, representing six orders and 27 families of landbirds breed in the areas in and adjacent to the Nushagak and Kvichak watersheds (USFWS, 2008; USFWS, 2010b). Published surveys of birds in this area include biological inventories from 1902 through 1959 (Gabrielson, 1944a; Gabrielson, 1944b; Hurley, 1931a; Hurley, 1931b; Hurley, 1931c; Hurley, 1932; Osgood, 1904; Williamson and Peyton, 1962). More recent work in this and adjacent areas include: inventories in the Kilbuck and Ahklun Mountains (Petersen et al., 1991), inventories in the montane regions of Lake Clark and Katmai NPPs (Ruthrauff et al., 2007), breeding bird surveys in Dillingham, Katmai, and King Salmon, and Christmas Bird Counts in Dillingham and King Salmon (National Audubon Society: http://audubon2.org/cbchist/count_table.html). "Landbirds" are species that are generally associated with terrestrial habitats: passerines (or "songbirds") and other species such as woodpeckers, owls, raptors, and gallinaceous birds (grouse and ptarmigan). Bald eagles are addressed separately in this document.

Landbirds common in the region during the summer breeding season include, but are not limited to, Swainson's thrush (*Catharus ustulatus*), American robin (*Turdus migratorius*), varied thrush (*Ixoreus naevius*), Arctic warbler (*Phylloscopus borealis*), orange-crowned warbler (*Vermivora celata*), and Wilson's warbler (*Wilsonia pusilla*) (USGS, 2011). Numerous other songbirds regularly nest here, including several other species of swallows (*Hirundinidae*), thrushes (*Turdidae*), warblers (*Parulidae*), sparrows (*Emberizidae*), and others. Year-round resident species include northern goshawk (*Accipiter gentilis*), great-horned owl, common raven (*Corvus corax*), gray jay (*Perisoreus canadensis*), black-billed magpie (*Pica pica*), black-capped and boreal chickadees (*Poecile atricapillus* and *P. hudsonicus*), American dipper (*Cinclus mexicanus*), common redpoll (*Carduelis flammea*), and snow bunting (*Plectrophenax nivalis*) (ADNR, 2008; USGS, 2011). Of the relatively common species occurring in the area, two (short-eared owl (*Asio flammeus*) and rusty blackbird (*Euphagus carolinus*)) are on the Continental Watch List. Twenty-six of the Bristol Bay landbird species are on the Continental Stewardship list for Partners in Flight, a multi-stakeholder partnership dedicated to the conservation of landbirds (Rich et al., 2004).

Habitat

Most species of landbirds occupy and defend individual breeding territories during the spring and summer. Few studies have focused on landbirds in the Nushagak and Kvichak watersheds and site-specific information is extremely sparse. Migratory species begin arriving in late April and may remain through late September (Savage, personal communication).

The Nushagak and Kvichak watersheds are within, albeit near the border of, the Arctic avifaunal biome, as described by Partners in Flight (Rich et al., 2004). The diversity, population, distribution, and densities of birds here are not well-understood. While no comprehensive studies have been published for these watersheds, land bird density and diversity, generally speaking, may be highest along the numerous riparian corridors of the region (Boreal Partners in Flight Working Group, 1999; Williamson and Peyton, 1962). Greater landbird densities in the riparian zone often occur in areas where the surrounding habitats have lower plant species or canopy layer diversity (Stauffer and Best, 1980; Wiebe and Martin, 1998). Riparian habitats in these

watersheds include ribbons of tall shrub (willow/cottonwood/alder), as well as spruce, birch and mixed forests, which wind and branch across vast acreages of moist and wet tundra (ADF&G, 2006; Nushagak-Mulchatna Watershed Council, 2007).

From the sparse site-specific data available, we are able to collect the following information to begin a characterization of local species diversity. For the Western Alaska Lowlands/Uplands Bird Conservation Region 2 (BCR 2), which includes the Ahklun Mountains and Bristol Bay-Nushagak Lowlands, passerine diversity is thought to be greatest in riparian tall shrub habitats (Boreal Partners in Flight Working Group, 1999).[5] Sixteen species of passerines, one woodpecker species, and belted kingfisher have been recorded along the Alagnak River (Gotthardt et al., 2010), although proximity to the river and whether or not the records were associated with riparian habitats is unknown.

Mixed spruce-birch forests of the area may also have a relatively high species diversity, with 25 to 27 species noted by Williamson and Peyton (1962). Forty species were recorded in plots in LCNPP, within the upper Mulchatna and upper Kvichak watersheds; the survey area likely included some non-riparian areas (Ruthrauff et al., 2007).

No site-specific density information is available for the Bristol Bay watershed. Regarding potential densities, Kessel reported between 11.8 and 45.4 passerine/woodpecker breeding territories per 10-hectare plot (mostly riparian) in Interior Alaska, (Kessel, 1998). However, significantly wide ranges of variability in landbird breeding densities reduce any potential usefulness of these figures for the local area.

Landbird diet requirements vary by species and time of year; foods include: vegetation (seeds, berries), invertebrates (aquatic and terrestrial, as well as flying insects), and vertebrates (other birds, fish and mammalian carrion, juvenile fish, fish eggs). During the breeding season, adults face high demands, associated with producing eggs, feeding young, and molting; young birds require considerable food resources to grow and both young and adults must gain fat prior to migration. Even birds that consume a high proportion of seeds and other vegetative matter in the non-breeding season may switch to food in higher trophic levels during the breeding season. In general, the timing of hatch and the growth of young landbirds is directly related to the abundance of invertebrate food sources (Ehrlich et al., 1988). In fact, the abundance of emergent aquatic insects may be one of the reasons riparian habitats are often associated with greater avian abundance (Iwata et al., 2003; Murakami and Nakano, 2002). Foraging techniques for avian predators of invertebrates (e.g., foliage gleaning, ground foraging, aerial predating/flycatching) vary considerably among species, however, so landbirds can exploit a variety of riparian invertebrate prey types overall (Murakami and Nakano, 2001).

Interspecies Interactions

Regarding the importance of salmon to landbirds, recent studies have indicated that the abundance of many species of songbirds is related to the presence of salmon carcasses in

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[5] BCR 2 includes most of the middle and lower areas of the Nushagak and Kvichak watersheds, but extends beyond them, from the Kuskokwim River to Unimak Pass.

freshwater streams (Christie and Reimchen, 2008; Gende and Willson, 2001; Willson et al., 1998). The relationship is complex and not yet fully understood (Christie and Reimchen, 2008; Gende et al., 2002). One primary component, though, appears to be the initial positive effect of the seasonal accumulation of carcasses on invertebrate populations (Helfield and Naiman, 2006). For example, masses of aquatic invertebrate larvae feed on salmon carcasses (Wipfli et al., 1999), over-winter in the soil, and emerge in the spring as adults, subsequently becoming aerial prey for songbirds, an important seasonal subsidy that becomes available during the same period when terrestrial invertebrate biomass is low (Nakano and Murakami, 2001). Terrestrial invertebrate (e.g., litter detritivore) populations may also increase as a result of salmon carcass abundance, providing another important food source for passerines (Gende and Willson, 2001). Passerines such as Pacific wren (*Troglodytes pacificus*) and other species also feed directly on fly larvae within dead salmon in the fall (Christie and Reimchen, 2008).

Other important relationships between salmon and landbirds include the effects of increased plant productivity, particularly in riparian areas, that appears to result from MDN input from salmon (Gende et al., 2002; Helfield and Naiman, 2001; Hilderbrand et al., 2004; Naiman et al., 2002a). This increased productivity, reflected, for example, in an abundance of berries and seeds, in turn provides an increased vegetative food source for landbirds such as Swainson's and varied thrushes (Christie and Reimchen, 2008). Another positive effect of spawning salmon on Alaska landbirds is indicated in the case of American dippers. Dippers feed primarily on aquatic invertebrates, which appear to increase in abundance with salmon carcasses, and females switch to salmon eggs, fry, and small bits of carcasses during the egg-laying period (Morrissey et al., 2010). In one study of dippers, there was an apparent positive correlation between consumption of salmon fry and higher fledgling mass and less brood mortality (Obermeyer et al., 2006).

As noted above, the trophic relationships among salmon, landbirds, invertebrate prey items, and other organisms are complex, and not yet well understood, particularly in relatively remote and undisturbed boreal regions, such as the Nushagak and Kvichak watersheds. However, these relationships are apparently significant to many aspects of landbird life history. In summary, abundance, distribution, productivity, habitat use, and foraging habits are some of the ways in which multiple species of landbirds may be affected by salmon. The temporal nature of the pulses of the abundant food source salmon provide is of particular interest. Several researchers have examined such seasonal resource subsidies in the riparian forest and it has been suggested (Takimoto et al., 2002) that seasonal productivity differences between spatially linked habitats help foster the stability of food web dynamics (Wiebe and Martin, 1998; Zhang et al., 2003).

APPENDIX 1: LIST OF AUTHORS AND REVIEWERS

Species	Primary Author(s) (Affiliation)	Expert Reviewer (Affiliation)
Overall Report	• Phil Brna (USFWS/AFWFO) • Lori Verbrugge (USFWS/AFWFO)	
Land Cover	• Phil Brna (USFWS/AFWFO)	• David Selkowitz (USGS/ Alaska Science Center) • Jerry Tande (USFWS/NWI Program) • Julie Michaelson (USFWS/NWI Program) • Marcus Geist (The Nature Conservancy)
Brown Bear	• Colleen Matt (C.A. Matt; ADF&G/ Retired)	• Sterling Miller (ADF&G/Retired) • Sean Farley (ADF&G) • Grant Hilderbrand (NPS) • Cara Staab (BLM) • Susan Savage (USFWS/Alaska Peninsula-Becharof NWRs) • Patrick Walsh (USFWS/Togiak NWR) • Buck Mangipane (NPS/ Lake Clark NP) • Page Spencer (NPS/Retired) • Lem Butler (ADF&G/Wildlife Conservation) • Meghan Riley (ADF&G/Wildlife Conservation) • Jim Woolington (ADF&G/Wildlife Conservation)
Caribou	• Lori Verbrugge (USFWS/AFWFO) • Ken Whitten (ADF&G/Retired)	• Layne Adams (USGS/Alaska Science Center) • Dominique Watts (USFWS/Alaska Peninsula-Becharof NWRs) • Bob Tobey (ADF&G/Retired) • Andy Aderman (USFWS/Togiak NWR) • Buck Mangipane (NPS/Lake Clark NP) • Cara Staab (BLM) • Jeff Shearer (NPS/Lake Clark NP) • Lem Butler (ADF&G/Wildlife Conservation) • Meghan Riley (ADF&G/Wildlife Conservation) • Jim Woolington (ADF&G/Wildlife

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		Conservation)
		• Nick Demma (ADF&G/Wildlife Conservation)
		• Bruce Seppi (BLM)
Moose	• Lori Verbrugge (USFWS/AFWFO) • Chuck Schwartz (ADF&G and USGS/Retired)	
Wolf	• Lori Verbrugge (USFWS/AFWFO)	• Layne Adams (USGS/Alaska Science Center) • Buck Mangipane (NPS/Lake Clark NP) • Dominique Watts (USFWS/Alaska Peninsula- Becharof NWRs) • Ashley Stanek (UAA/ENRI) • Ken Whitten (ADF&G/Retired) • Bob Tobey (ADF&G/Retired) • Cara Staab (BLM) • Bruce Seppi (BLM) • Page Spencer (NPS/Retired)
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Landbirds	• Maureen de Zeeuw (USFWS/AFWFO) • Susan Savage (USFWS/Alaska Peninsula-Becharof NWRs)	• Meghan Riley (ADF&G/Wildlife Conservation)
Shorebirds	• Susan Savage (USFWS/Alaska Peninsula-Becharof NWRs)	• Bob Gill (USGS/Alaska Science Center) • Heather Coletti (NPS/Lake Clark NP) • Rick Lanctot (USFWS/Migratory Birds) • Steve Kendall (USFWS)
Waterfowl	• Tom Rothe (Halcyon Research; ADF&G/ Retired)	• Christian Dau (USFWS/Migratory Birds) • Maureen de Zeeuw (USFWS/AFWFO)
Species List	• Maureen de Zeeuw (USFWS/AFWFO) • Susan Savage (USFWS/Alaska Peninsula-Becharof NWRs)	

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APPENDIX 2: SOUTHWEST ALASKA TERRESTRIAL VERTEBRATE SPECIES

BIRDS
(Togiak NWR, Bird List 2006; D. Ruthrauff et al. 2007; Alaska Peninsula and Becharof NWR Bird List, 2010; with edits from S. Savage, M. Swaim, D. Ruthrauff)

The following species are thought to regularly occur in the Nushagak and Kvichak watersheds based on surveys and observations documenting their presence in adjacent federal land management areas. The species are marked as breeders if they are known to breed in the adjacent areas. Other species that may occur as accidentals are not included here.

Common Name	Scientific Name	Breeder
Waterfowl		
Greater White-fronted Goose	*Anser albifrons*	*
Emperor Goose	*Chen canagica*	*
Snow Goose	*Chen caerulescens*	
Brant	*Branta bernicla*	*
Cackling Goose	*Branta hutchinsii*	
Canada Goose	*Branta canadensis*	*
Trumpeter Swan	*Cygnus buccinator*	*
Tundra Swan	*Cygnus columbianus*	*
Gadwall	*Anas strepera*	*
Eurasian Wigeon	*Anas penelope*	
American Wigeon	*Anas americana*	*
Mallard	*Anas platyrhynchos*	*
Northern Shoveler	*Anas clypeata*	*
Northern Pintail	*Anas acuta*	*
Green-winged Teal	*Anas crecca*	*
Canvasback	*Aythya valisineria*	
Redhead	*Aythya americana*	
Ring-necked Duck	*Aythya collaris*	*
Greater Scaup	*Aythya marila*	*
Lesser Scaup	*Aythya affinis*	
Steller's Eider	*Polysticta stelleri*	
Spectacled Eider	*Somateria fischeri*	
King Eider	*Somateria spectabilis*	
Common Eider	*Somateria mollissima*	*
Harlequin Duck	*Histrionicus histrionicus*	*
Surf Scoter	*Melanitta perspicillata*	*
White-winged Scoter	*Melanitta fusca*	*
Black Scoter	*Melanitta americana*	*
Long-tailed Duck	*Clangula hyemalis*	*

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Common Name	**Scientific Name**	**Breeder**
Bufflehead	*Bucephala albeola*	*
Common Goldeneye	*Bucephala clangula*	*
Barrow's Goldeneye	*Bucephala islandica*	
Common Merganser	*Mergus merganser*	*
Red-breasted Merganser	*Mergus serrator*	*

Gallinaceous Birds

Spruce Grouse	*Falcipennis canadensis*	*
Willow Ptarmigan	*Lagopus lagopus*	*
Rock Ptarmigan	*Lagopus muta*	*
White-tailed Ptarmigan	*Lagopus leucura*	*

Loons

Red-throated Loon	*Gavia stellata*	*
Pacific Loon	*Gavia pacifica*	*
Common Loon	*Gavia immer*	*

Grebes

Horned Grebe	*Podiceps auritus*	*
Red-necked Grebe	*Podiceps grisegena*	*

Tubenoses

Northern Fulmar	*Fulmarus glacialis*	
Sooty Shearwater	*Puffinus griseus*	
Short-tailed Shearwater	*Puffinus tenuirostris*	
Fork-tailed Storm-Petrel	*Oceanodroma furcata*	
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	

Cormorants

Double-crested Cormorant	*Phalacrocorax auritus*	*
Red-faced Cormorant	*Phalacrocorax urile*	*
Pelagic Cormorant	*Phalacrocorax pelagicus*	*

Hawks, Eagles, Falcons

Osprey	*Pandion haliaetus*	*
Bald Eagle	*Haliaeetus leucocephalus*	*
Northern Harrier	*Circus cyaneus*	*
Sharp-shinned Hawk	*Accipiter striatus*	
Northern Goshawk	*Accipiter gentilis*	*
Red-tailed Hawk	*Buteo jamaicensis*	*
Rough-legged Hawk	*Buteo lagopus*	*
Golden Eagle	*Aquila chrysaetos*	*

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Common Name	Scientific Name	Breeder
American Kestrel	*Falco sparverius*	
Merlin	*Falco columbarius*	*
Gyrfalcon	*Falco rusticolus*	*
Peregrine Falcon	*Falco peregrinus*	*

Cranes

Sandhill Crane	*Grus canadensis*	*

Shorebirds

Black-bellied Plover	*Pluvialis squatarola*	*
American Golden-Plover	*Pluvialis dominica*	*
Pacific Golden-Plover	*Pluvialis fulva*	*
Semipalmated Plover	*Charadrius semipalmatus*	*
Black Oystercatcher	*Haematopus bachmani*	*
Spotted Sandpiper	*Actitis macularius*	*
Solitary Sandpiper	*Tringa solitaria*	
Wandering Tattler	*Tringa incana*	*
Greater Yellowlegs	*Tringa melanoleuca*	*
Lesser Yellowlegs	*Tringa flavipes*	*
Whimbrel	*Numenius phaeopus*	*
Bristle-thighed Curlew	*Numenius tahitiensis*	
Hudsonian Godwit	*Limosa haemastica*	*
Bar-tailed Godwit	*Limosa lapponica*	*
Marbled Godwit	*Limosa fedoa*	*
Ruddy Turnstone	*Arenaria interpres*	
Black Turnstone	*Arenaria melanocephala*	*
Surfbird	*Aphriza virgata*	*
Red Knot	*Calidris canutus*	
Sanderling	*Calidris alba*	
Semipalmated Sandpiper	*Calidris pusilla*	
Western Sandpiper	*Calidris mauri*	*
Least Sandpiper	*Calidris minutilla*	*
Baird's Sandpiper	*Calidris bairdii*	*
Pectoral Sandpiper	*Calidris melanotos*	*
Rock Sandpiper	*Calidris ptilocnemis*	*
Dunlin	*Calidris alpina*	*
Short-billed Dowitcher	*Limnodromus griseus*	*
Long-billed Dowitcher	*Limnodromus scolopaceus*	
Wilson's Snipe	*Gallinago delicata*	*
Red-necked Phalarope	*Phalaropus lobatus*	*
Red Phalarope	*Phalaropus fulicarius*	

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Common Name	Scientific Name	Breeder
Gulls and Terns		
Black-legged Kittiwake	*Rissa tridactyla*	*
Sabine's Gull	*Xema sabini*	*
Bonaparte's Gull	*Chroicocephalus philadelphia*	*
Mew Gull	*Larus canus*	*
Herring Gull	*Larus argentatus*	
Slaty-backed Gull	*Larus schistisagus*	
Glaucous-winged Gull	*Larus glaucescens*	*
Glaucous Gull	*Larus hyperboreus*	*
Aleutian Tern	*Onychoprion aleuticus*	*
Arctic Tern	*Sterna paradisaea*	*
Jaegers		
Pomarine Jaeger	*Stercorarius pomarinus*	
Parasitic Jaeger	*Stercorarius parasiticus*	*
Long-tailed Jaeger	*Stercorarius longicaudus*	*
Alcids		
Common Murre	*Uria aalge*	*
Thick-billed Murre	*Uria lomvia*	*
Pigeon Guillemot	*Cepphus columba*	*
Marbled Murrelet	*Brachyramphus marmoratus*	*
Kittlitz's Murrelet	*Brachyramphus brevirostris*	*
Ancient Murrelet	*Synthliboramphus antiquus*	
Parakeet Auklet	*Aethia psittacula*	*
Rhinoceros Auklet	*Cerorhinca monocerata*	
Horned Puffin	*Fratercula corniculata*	*
Tufted Puffin	*Fratercula cirrhata*	*
Owls		
Great Horned Owl	*Bubo virginianus*	*
Snowy Owl	*Bubo scandiacus*	
Northern Hawk Owl	*Surnia ulula*	*
Great Gray Owl	*Strix nebulosa*	*
Short-eared Owl	*Asio flammeus*	*
Boreal Owl	*Aegolius funereus*	*
Northern Saw-whet Owl	*Aegolius acadicus*	*
Hummingbirds		
Rufous Hummingbird	*Selasphorus rufus*	

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Common Name	Scientific Name	Breeder
Kingfishers		
Belted Kingfisher	*Megaceryle alcyon*	*
Woodpeckers		
Downy Woodpecker	*Picoides pubescens*	*
Hairy Woodpecker	*Picoides villosus*	
American Three-toed Woodpecker	*Picoides dorsalis*	*
Black-backed Woodpecker	*Picoides arcticus*	*
Northern Flicker	*Colaptes auratus*	*
Flycatchers		
Olive-sided Flycatcher	*Contopus cooperi*	
Alder Flycatcher	*Empidonax alnorum*	*
Say's Phoebe	*Sayornis saya*	
Shrikes		
Northern Shrike	*Lanius excubitor*	*
Crows, Jays, Magpies		
Gray Jay	*Perisoreus canadensis*	*
Steller's Jay	*Cyanocitta stelleri*	
Black-billed Magpie	*Pica hudsonia*	*
Northwestern Crow	*Corvus caurinus*	*
Common Raven	*Corvus corax*	*
Larks		
Horned Lark	*Eremophila alpestris*	*
Swallows		
Tree Swallow	*Tachycineta bicolor*	*
Violet-green Swallow	*Tachycineta thalassina*	*
Bank Swallow	*Riparia riparia*	*
Cliff Swallow	*Petrochelidon pyrrhonota*	*
Barn Swallow	*Hirundo rustica*	*
Chickadees		
Black-capped Chickadee	*Poecile atricapillus*	*
Boreal Chickadee	*Poecile hudsonicus*	*
Nuthatches		
Red-breasted Nuthatch	*Sitta canadensis*	*

Common Name	Scientific Name	Breeder

Creepers
Brown Creeper — *Certhia americana* — *

Wrens
Pacific Wren — *Troglodytes pacificus* — *

Dippers
American Dipper — *Cinclus mexicanus* — *

Kinglets
Golden-crowned Kinglet — *Regulus satrapa* — *
Ruby-crowned Kinglet — *Regulus calendula* — *

Old World Warblers
Arctic Warbler — *Phylloscopus borealis* — *

Thrushes
Northern Wheatear — *Oenanthe oenanthe*
Gray-cheeked Thrush — *Catharus minimus* — *
Swainson's Thrush — *Catharus ustulatus* — *
Hermit Thrush — *Catharus guttatus* — *
American Robin — *Turdus migratorius* — *
Varied Thrush — *Ixoreus naevius* — *

Watgtails and Pipits
Eastern Yellow Wagtail — *Motacilla tschutschensis* — *
American Pipit — *Anthus rubescens* — *

Waxwings
Bohemian Waxwing — *Bombycilla garrulus* — *

Longspurs and Buntings
Lapland Longspur — *Calcarius lapponicus* — *
Snow Bunting — *Plectrophenax nivalis* — *
McKay's Bunting — *Plectrophenax hyperboreus*

Wood Warblers
Northern Waterthrush — *Parkesia noveboracensis* — *
Orange-crowned Warbler — *Oreothlypis celata* — *
Yellow Warbler — *Setophaga petechia* — *
Blackpoll Warbler — *Setophaga striata* — *

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Common Name	Scientific Name	Breeder
Yellow-rumped Warbler	*Setophaga coronata*	*
Wilson's Warbler	*Cardellina pusilla*	*

Sparrows

American Tree Sparrow	*Spizella arborea*	*
Savannah Sparrow	*Passerculus sandwichensis*	*
Fox Sparrow	*Passerella iliaca*	*
Song Sparrow	*Melospiza melodia*	*
Lincoln's Sparrow	*Melospiza lincolnii*	*
White-crowned Sparrow	*Zonotrichia leucophrys*	*
Golden-crowned Sparrow	*Zonotrichia atricapilla*	*
Dark-eyed Junco	*Junco hyemalis*	*

Blackbirds

Rusty Blackbird	*Euphagus carolinus*	*

Finches

Gray-crowned Rosy-Finch	*Leucosticte tephrocotis*	*
Pine Grosbeak	*Pinicola enucleator*	*
Red Crossbill	*Loxia curvirostra*	
White-winged Crossbill	*Loxia leucoptera*	*
Common Redpoll	*Acanthis flammea*	*
Hoary Redpoll	*Acanthis hornemanni*	*
Pine Siskin	*Spinus pinus*	

MAMMALS
(Cook and MacDonald, 2005; USFWS, 2009b)

Common Name	Scientific Name

Terrestrial Mammals

Shrews

Masked shrew	*Sorex cinereus*
Pygmy shrew	*Sorex hoyi*
Tundra shrew	*Sorex tundrensis*
Alaska tiny shrew	*Sorex yukonicus*
Arctic shrew	*Sorex arcticus*
Montane shrew	*Sorex monticolus*
Northern water shrew	*Sorex palustris*

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Common Name	Scientific Name
Bats	
Little brown bat	*Myotis lucifigus*
Canids	
Arctic fox	*Alopex lagopus*
Coyote	*Canis latrans*
Wolf	*Canis lupus*
Red fox	*Vulpes vulpes*
Cats	
Lynx	*Lynx canadensis*
Weasels	
River otter	*Lutra canadensis*
Wolverine	*Gulo gulo*
Marten	*Martes americana*
Ermine	*Mustela erminea*
Least weasel	*Mustela nivalis*
Mink	*Mustela vison*
Bears	
Black bear	*Ursus americanus*
Brown bear	*Ursus arctos*
Ungulates	
Moose	*Alces alces*
Caribou	*Rangifer tarandus*
Dall sheep	*Ovis dalli*
Rodents	
Hoary marmot	*Marmota caligata*
Arctic ground squirrel	*Spermophilus parryii*
Red squirrel	*Tamiasciurus hudsonicus*
Beaver	*Castor canadensis*
Meadow jumping mouse	*Zapus hudsonius*
Northern red-backed vole	*Clethrionomys rutilus*
Northern collared lemming	*Dicrostonyx groenlandicus*
Brown lemming	*Lemmus trimucronatus*
Northern bog lemming	*Synaptomys borealis*
Meadow vole	*Microtus pennsylvanicus*
Tundra vole	*Microtus oeconomus*
Singing vole	*Microtus miurus*
Muskrat	*Ondatra zibethicus*
Porcupine	*Erethizon dorsatum*
Collared pika	*Ondatra collaris*

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Common Name	**Scientific Name**
Hares	
Snowshoe hare	*Lepus americanus*
Tundra hare	*Lepus othus*

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APPENDIX 3: LITERATURE CITED

Adams L. (personal communication) Email from L. Adams, USGS to Guy Adema, NPS dated 01/04/2012.

Adams L.G., Farley S.D., Stricker C.A., Demma D.J., Roffler G.H., Miller D.C., Rye R.O. (2010) Are inland wolf-ungulate systems influenced by marine subsidies of Pacific salmon? Ecological Applications 20:251-262.

Adams L.G., Stephenson R.O., Dale B.W., Ahgook R.T., Demma D.J. (2008) Population dynamics and harvest characteristics of wolves in the Central Brooks Range, Alaska. Wildlife Monographs 170:1-25.

Aderman A.R. (2009) Population monitoring and status of the Nushagak Peninsula caribou herd, 1988-2008. Progress Report, Togiak National Wildlife Refuge, Dillingham, Alaska. pp. 29.

Aderman A.R., Lowe S.J. (2011) Population monitoring and status of the Nushagak Peninsula caribou herd, 1988-2011. Draft progress report, Togiak National Wildlife Refuge, Dillingham, Alaska. pp. 29.

Aderman A.R., Woolington J.D. (2001) Population monitoring and status of the reintroduced Nushagak Peninsula caribou herd. Progress report, U.S. Fish and Wildlife Service, Togiak National Wildlife Refuge, Dillingham, AK.

ADF&G. (1985) Alaska Habitat Management Guide, Southwest Region Volume 1: Fish and Wildlife Life Histories, Alaska Department of Fish and Game, Juneau, AK.

ADF&G. (2006) Our wealth maintained: a strategy for conserving Alaska's diverse wildlife and fish resources, Alaska Department of Fish and Game, Juneau, AK. pp. xviii+824.

ADF&G. (2009) Brown Bear Management report of survey-inventory activities 1 July 2006-30 June 2008 Alaska Department of Fish and Game, Juneau, AK. pp. 336 pgs.

ADF&G. (2010) Trapper Questionnaire: Statewide Annual Report, 1 July 2008 - 30 June 2009, Alaska Department of Fish and Game, Division of Wildlife Conservation, Juneau, AK.

ADF&G. (2011a) 2011-2012 Alaska hunting regulations. No. 52, Alaska Department of Fish and Game, Juneau, AK.

ADF&G. (2011b) 2011 - 2012 Alaska Trapping Regulations, Alaska Department of Fish and Game, Juneau, AK.

ADF&G. (2011c) 2012 Togiak herring forecast. , News release Nov 10, 2011. , Alaska Dept. Fish and Game Juneau.

ADF&G. (2011d) Moose Species Profile, Alaska Department of Fish and Game, Juneau, AK.

ADNR. (2008) Bristol Bay Coastal Resource Service Area Coastal Management Plan, Alaska Department of Natural Resources. pp. 132.

Alaska Migratory Bird Co-Management Council. (2003) Recommendations for a statewide Alaska migratory bird subsistence harvest survey. Unpublished, Ad hoc Subsistence Harvest Survey Committee, c/o U.S. Fish and Wildlife Service, Anchorage, AK.

Alaska Natural Heritage Program. (2011) http://aknhp.uaa.alaska.edu/.

Alaska Shorebird Group. (2008) Alaska Shorebird Conservation Plan. Version II, Alaska Shorebird Group, Anchorage, AK.

American Ornithologists' Union. (2011) North American Classification Committee (NACC), statement on treatment of subspecies. http://www.aou.org/committees/nacc/.

Anthony R.G. (2001) Low productivity of Bald Eagles on Prince of Wales Island, Southeast Alaska. Journal of Raptor Research 35:1-8.

Anthony R.G., Isaacs F.B. (1989) Characteristics of Bald Eagle nest sites in Oregon. Journal of Wildlife Management 53:148-159.

Anthony R.G., Knight R.L., Allen G.T., McClelland B.R., Hodges J.I. (1982) Habitat use by nesting and roosting Bald Eagles in the Pacific Northwest, in: K. Sabol (Ed.), Transactions of the 47th North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Washington D.C. pp. 332-342.

Anthony R.G., Miles A.K., Estes J.A., Isaacs F.B. (1999) Productivity, diets, and environmental contaminants in nesting Bald Eagles from the Aleutian Archipelago. Environmental Toxicology and Chemistry 18:2054-2062.

Anthony R.G., Miles A.K., Ricca M.A., Estes J.A. (2007) Environmental contaminants in bald eagle eggs from the Aleutian archipelago. Environmental Toxicology and Chemistry 26:1843-1855.

Armstrong R.H. (2010) The importance of fish to Bald Eagles in Southeast Alaska: a review, in: B. A. Wright and P. Schempf (Eds.), Bald Eagles in Alaska, Hancock House Publishers, Surrey, British Columbia, Canada. pp. 54-67.

Arneson P.D. (1978) Annual Report: Identification, documentation and delineation of coastal migratory bird habitat in Alaska, Alaska Department of Fish and Game.

Arneson P.D. (1980) Identification, documentation, and delineation of coastal migratory bird habitat in Alaska. Final report, OCS contract #03-5-022-69. Environmental Assessment of the Alaska Continental Shelf, BLM/NOAA Outer Continental Shelf Environmental Assessment Program, Boulder, CO. pp. 350.

Aumiller L.D., Matt C.A. (1994) Management of the McNeil River State Game Sanctuary for viewing of Alaskan brown bears. Int. Conf. Bear Res. and Manage. 9:51-61.

Ballard W.B., Ayres L.A., Krausman P.R., Reed D.J., Fancy S.G. (1997) Ecology of wolves in relation to a migratory caribou herd in northwest Alaska. Wildlife Monographs 135:1-47.

Ballard W.B., Dau J.R. (1983) Characteristics of gray wolf den and rendezvous sites in south-central Alaska. Canadian Field-Naturalist 97:299-302.

Ballard W.B., Edwards M., Fancy S.G., Boe S., Krausman P.R. (1998) Comparison of VHF and satellite telemetry for estimating sizes of wolf territories in northwest Alaska. Wildlife Society Bulletin 26:823-829.

Ballard W.B., Gardner C.L., Miller S.D. (1980) Influence of predators on summer movements of moose in southcentral Alaska. Proceedings of the North American Moose Conference Workshop 16:338-359.

Ballard W.B., Lutz D., Keegan T.W., Carpenter L.H., deVos J.C. (2001) Deer-predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin 29:99-115.

Ballard W.B., Miller S.D., Spraker T.H. (1982) Home range, daily movements, and reproductive biology of brown bears in southcentral Alaska. Canadian Field-Naturalist 96:1-5.

Ballard W.B., Spraker T.H., Taylor K.P. (1981) Causes of neonatal moose calf mortality in southcentral Alaska. Journal of Wildlife Management 45:335-342.

Ballard W.B., Van Ballenberghe V. (2007) Predator/prey relationships, in: A. W. Franzmann and C. C. Schwartz (Eds.), Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 247-273.

Ballard W.B., Whitman J.S., Garden C.L. (1987) Ecology of an exploited wolf population in southcentral Alaska. Wildlife Monographs 98:1-54.

128

Ballard W.B., Whitman J.S., Reed D.J. (1991) Population dynamics of moose in south-central Alaska. Wildlife Monographs 114:1-49.

Ballew C., Ross A., Wells R.S., Hiratsuka V., Hamrick K.J., Nobmann E.D., Bartell S. (2004) Final report on the Alaska Traditional Diet Survey, Alaska Native Health Board, Anchorage, AK.

Bangs E.E., Bailey T.N. (1980) Moose movements and distribution in response to winter seismological exploration on the Kenai National Wildlife Refuge, Alaska, U.S. Fish and Wildlife Service, Kenai National Wildlife Refuge, Kenai, Alaska. pp. 47.

Bangs E.E., Bailey T.N., Berns V.D. (1982a) Ecology of nesting Bald Eagles on the Kenai National Wildlife Refuge, Alaska, in: W. N. Ladd and P. F. Schempf (Eds.), Proceedings of 1st Annual Raptor Management Symposium, U.S. Fish and Wildlife Service, Anchorage, AK. pp. 47-54.

Bangs E.E., Bailey T.N., Portner M.F. (1984) Bull moose behavior and movements in relation to harvest on the Kenai National Wildlife Refuge. Alces 20:187-208.

Bangs E.E., Bailey T.N., Portner M.F. (1989) Survival rates of adult female moose on the Kenai Peninsula, Alaska. Journal of Wildlife Management 53:557-563.

Bangs E.E., Duff S.A., Bailey T.N. (1985) Habitat differences and moose use of two large burns on the Kenai Peninsula, Alaska. Alces 21:17-35.

Bangs E.E., Spraker T.H., Bailey T.N., Berns V.D. (1982b) Effects of increased human populations on wildlife resources of the Kenai Peninsula, Alaska. Transactions of the North American Wildlife Natural Resources Conference 47:605-616.

Barboza P.S., Bowyer R.T. (2000) Sexual segregation in dimorphic deer: a new gastrocentric hypothesis. Journal of Mammalogy 81:473-489.

Bartonek J.C., Gibson D.D. (1972) Summer distribution of pelagic birds in Bristol Bay, Alaska. Condor 74:416-422.

Bartz K.K., Naiman R.J. (2005) Effects of salmon-borne nutrients on riparian soils and vegetation in Southwest Alaska. Ecosystems 8:529-545.

Battley P.F., Warnock N., Tibbitts T.L., Gill R.E., Piersma T., Hassell C.J., Douglas D.C., Mulcahy D.M., Gartrell B.D., Schuckard R., Melville D.S., Riegen A.C. (2011) Trans-hemispheric migration timing, flight paths and staging in two bar-tailed godwit subspecies. Journal of Avian Biology in press.

Bayer R.D. (1980) Birds feeding on herring eggs at the Yaquina Estuary, Oregon. Condor 82:193-198.

Bayley S.E., Schindler D.W., Beaty K.G., Parker B.R., Stainton M.P. (1992) Effects of multiple fires on nutrient yields from streams draining boreal forest and fen watersheds: nitrogen and phosphorus. Can. J. Fish. Aquat. Sci 40:584-596.

Becker E. (2010) Preliminary final report on monitoring the brown bear population affected by development associated with the proposed Pebble mine project, Alaska Department of Fish and Game, Anchorage, AK.

Bedard J., Crete M., Audy E. (1978) Short-term influence of moose upon woody plants of an early seral wintering site in Gaspe Peninsula, Quebec. Canadian Journal of Forest Research 8:407-415.

Behnke S.R. (1982) Wildlife utilization and the economy of Nondalton. Technical Paper No. 47, Division of Subsistence, Alaska Department of Fish and Game, Juneau, AK.

Bellrose F.C. (1980) Ducks, geese and swans of North America Stackpole Books, Harrisburg, PA.

Ben-David M., Hanley T.A., Schell D.M. (1998) Fertilization of terrestrial vegetation by spawning Pacific salmon: the role of flooding and predator activity. Oikos 83:47-55.

Bengtson S.A. (1971) Food and feeding of diving ducks breeding at Lake M'yvatn, Iceland. Ornis Fennica 48:77-92.

Bennett A.J., Thompson W.L., Mortenson D.C. (2006) Vital signs monitoring plan, Southwest Alaska Network, National Park Service, Anchorage, AK.

Bergerud A.T. (1996) Evolving perspectives on caribou population dynamics, have we got it right yet? Rangifer Special Issue 9:95-116.

Bishop R.H., Rausch R.A. (1974) Moose population fluctuations in Alaska. Naturaliste Canada (Quebec) 101:559-593.

Boer A.W. (1992) Fecundity of North American moose (Alces alces): a review. Alces Supplement 1:1-10.

Boer A.W. (2007) Interspecific relationships, in: A. W. Franzmann and C. C. Schwartz (Eds.), Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 337-349.

Boertje R.D., Stephenson R.O. (1992) Effects of ungulate availability on wolf reproductive potential in Alaska. Canadian Journal of Zoology 70:2441-2443.

Bordage D., Savard J.P.L. (1995) American Scoter (Melanitta americana), No. 177, in: A. Poole and F. Gill (Eds.), The Birds of North America, Cornell Lab of Ornithology, Ithaca, NY.

Boreal Partners in Flight Working Group. (1999) Landbird conservation plan for Alaska biogeographic regions, Version 1.0. Unpublished, U.S. Fish and Wildlife Service, Anchorage, AK. pp. 45.

Bowman T., Schamber J., Esler D., Rosenberg D., Flint P., Stehn R., Pearce J. (2007) Assessment of the Pacific black scoter population: population size, distribution, and links among populations: an integrated approach. Unpublished progress report, Sea Duck Joint Venture Project 38, U.S. Fish and Wildlife Service, Anchorage, AK. pp. 10.

Bowyer R.T., Neville J.A. (2003) Effects of browsing history by Alaskan moose on regrowth and quality of feltleaf willow. Alces 39:193-202.

Bowyer R.T., Person D.K., Pierce B.M. (2005) Detecting top-down versus bottom-up regulation of ungulates by large carnivores: implications for conservation of biodiversity, in: J. C. Ray, et al. (Eds.), Large carnivores and the conservation of biodiversity, Island Press, Covelo, CA, USA. pp. 342-361.

Bowyer R.T., Pierce B.M., Duffy L.K., Haggstrom D.A. (2001) Sexual segregation in moose: effects of habitat manipulation. Alces 37:109-122.

Bowyer R.T., Stewart K.M., Wolfe S.A., Bundell G.M., Lehmkkuhl K.L., Joy P.J., McDonough T.J., Kei J.G. (2002) Assessing sexual segregation in deer. Journal of Wildlife Management 66:536-544.

Bowyer R.T., Van Ballenberghe V., Kie J.G. (1998) Timing and synchrony of parturition in Alaskan moose: long-term versus proximal effects of climate. Journal Of Mammalogy 79:1332-1344.

Bowyer R.T., Van Ballenberghe V., Kie J.G. (2003) Moose, in: G. A. Feldhamer, et al. (Eds.), Wild Mammals of North America: Biology, Management, and Conservation, John Hopkins University Press, Baltimore, Maryland. pp. 931-964.

Bowyer R.T., Van Ballenberghe V., Kie J.G., Maier J.A.K. (1999) Birth-site selection by Alaskan moose: maternal strategies for coping with a risky environment. Journal Of Mammalogy 80:1070-1083.

Bubenik A.B. (2007) Behavior, in: A. W. Franzmann and C. C. Schwartz (Eds.), Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 172-221.

Buehler D.A. (2000) Bald Eagle (Haliaeetus leucocephalus), Number 506, in: A. Poole and F. Gill (Eds.), The birds of North America, Academy of Natural Sciences, Philadelphia, Pennsylvania.

Burch J.W., Adams L.G., Follmann E.H., Rexstad E.A. (2005) Evaluation of wolf density estimation from radiotelemetry data. Wildlife Society Bulletin 33:1225-1236.

Burger J., Hahn D.C., Chase J. (1979) Aggressive interactions in mixed-species flocks of migrating shorebirds. Animal Behavior 27:459-469.

Burkholder B.L. (1959) Movements and behavior of a wolf pack in Alaska. Journal of Wildlife Management 23:1-11.

Butler L. (2009a) Units 9C & 9E caribou management report, in: P. Harper (Ed.), Caribou management report survey and inventory activities 1 July 2006-30 June 2008, Alaska Department of Fish and Game, Juneau, AK.

Butler L.B. (2009b) Unit 9 and 10 wolf management report, in: P. Harper (Ed.), Wolf management report of survey and inventory activities: 1 July 2005 - 30 June 2008, Alaska Department of Fish and Game, Juneau, AK.

Butler L.G. (2004) Unit 9 moose management report, in: C. Brown (Ed.), Moose management report of survey and inventory activities: 1 July 2001 - 30 June 2003, Alaska Department of Fish and Game, Juneau, AK. pp. 113-120.

Butler L.G. (2008) Unit 9 moose management report, in: P. Harper (Ed.), Moose management report of survey and inventory activities 1 July 2005-30 June 2007, Alaska Department of Fish and Game, Juneau, AK. pp. 116-124.

Byrne L.C., Daum D.W., Small M.W., Henderson J.S. (1983) Results of the 1981 Bald Eagle nest survey in the Gulkana River and Delta River wildlife habitat areas, BLM-Alaska Open File Report BLM/AK/OF-83-4.

Cain S.L. (1985) Nesting activity time budgets of Bald Eagles in Southeast Alaska, University of Montana, Missoula, MT. pp. 47.

Cameron R.D. (1994) Reproductive pauses by female caribou. Journal Of Mammalogy 75:10-13.

Cameron R.D., Whitten K.R. (1980) Influence of the Trans-Alaska Pipeline corridor on the local distribution of caribou, in: E. Reimers, et al. (Eds.), Proceedings of the 2nd International Reindeer/Caribou Symposium, Trondheim: Direktoratet for vilt og ferskvannsfisk, Roros, Norway, 1979. pp. 475-484.

Cameron R.D., Whitten K.R., Smith W.T. (1986) Summer range fidelity of radio-collared caribou in Alaska's Central Arctic Herd. Rangifer Special Issue 1:51-55.

Cameron R.D., Whitten K.R., Smith W.T., Roby D.D. (1979) Caribou distribution and group composition associated with construction of the Trans-Alaska Pipeline. Canadian Field-Naturalist 93:155-162.

Cantin M., Bédard J., Milne H. (1974) The food and feeding of common eiders in the St. Lawrence estuary. Can. J. Zool. 52:319-334.

Carnes J.C. (2004) Wolf ecology on the Copper and Bering River Deltas, Alaska, University of Idaho.

131

Cederholm C.I., Houston D.S., Cole D.L., Scarlett W.I. (1989) Fate of coho salmon (Oncorhynchus kisutch) carcasses in spawning streams. Can. J. Fish. Aquat. Sci 46 1347-1355.

Cederholm C.J., Kunze M.D., Murota T., Sibatani A. (1999) Pacific salmon carcasses: Essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. Fisheries 24:6-15.

Cederlund G., Sand H.K.G. (1991) Population dynamics and yield of a moose population without predators. Alces 27:31-40.

Child K.N. (2007) Incidental mortality, in: A. W. Franzmann and C. C. Schwartz (Eds.), Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 275-302.

Christie K.S., Reimchen T.E. (2005) Post-reproductive Pacific salmon, Oncorhynchus spp., as a major nutrient source for large aggregations of gulls, Larus spp. Canadian Field-Naturalist 119:202-207.

Christie K.S., Reimchen T.E. (2008) Presence of salmon increases passerine density on Pacific Northwest streams. Auk 125:51-59.

Christopher M.W., Hill E.P. (1988) Diurnal activity budgets of nonbreeding waterfowl and coots using catfish ponds in Mississippi. Proc. Ann. Conf. Southeast. Assoc. Fish Wildl. Agenc 42:520-527.

Coady J.W. (1980) History of moose in northern Alaska and adjacent regions. Canadian Field-Naturalist 94:61-68.

Coady J.W. (1982) Moose, in: J. A. Chapman and G. A. Feldhamer (Eds.), Wild mammals of North America, Johns Hopkins University Press, Baltimore, Maryland. pp. 902-922.

Collins G.H., Kovach S.D., Hinkes M.T. (2005) Home range and movements of female brown bears in southwest Alaska. Ursus 16:181-189.

Conant B., Groves D.J., Platte R.M. (2007) A comparative analysis of waterfowl breeding population surveys over tundra habitats in Alaska. Unpublished, U.S. Fish and Wildlife Service, Juneau, AK. pp. 32.

Connors P.G. (1978) Shorebird dependence on arctic littoral habitats, Environmental Assessment of the Alaskan continental shelf, NOAA/OCSEAP, Ann. Rep. 2:84-166.

Cook J.A., MacDonald A.O. (2005) Mammal inventory of Alaska's National Parks and Preserves, Southwest Alaska Network: Kenai Fjords National Park, Lake Clark National Park and Preserve, and Katmai National Park and Preserve. Inventory and Monitoring Program Final Report, National Park Service, Alaska Region. pp. 57.

Cooke F., Robertson G.J., Smith C.M., Goudie R.I., Boyd W.S. (2000) Survival, emigration, and winter population structure of harlequin ducks. Condor 102:137-144.

Cornell Lab of Ornithology. (2011) The Birds of North America.

Corr P.O. (1974) Bald Eagle (Haliaeetus leucocephalus) nesting related to forestry in Southeastern Alaska, University of Alaska, Fairbanks, AK.

Cottam C. (1939) Food habits of North American diving ducks, U.S. Dept of Agriculture, Washington, D.C.

Crawford D.L. (2001) Bristol Bay sockeye smolt studies for 2001, Alaska Dept. Fish and Game, Anchorage. pp. 97pp. + appendices.

Crete M. (1987) The impact of sport hunting on North American moose. Swedish Wildlife Research Supplement 1:553-563.

Crete M., Taylor R.J., Jordan P.A. (1981) Optimization of moose harvest in southwestern Quebec. Journal of Wildlife Management 45:598-611.

Crichton V.F.J. (1992) Six year (1986/87-1991/92) summary of in utero productivity of moose in Manitoba, Canada. Alces 28:203-214.

Darby W.R., Pruitt W.O. (1984) Habitat use, movements, and grouping behavior of woodland caribou, Rangifer tarandus caribou, in southeastern Manitoba. Canadian Field-Naturalist 97:184-190.

Darimont C.T., Paquet P.C. (2000) The Gray Wolves (Canis lupus) of British Columbia's Coastal Rainforests: Findings from year 2000 pilot study and conservation assessment, Raincoast Conservation Society, Victoria, B.C.

Darimont C.T., Paquet P.C. (2002) The gray wolves, Canis Lupus, of British Columbia's Central and North Coast: distribution and conservation assessment. Canadian Field-Naturalist 116:416-422.

Darimont C.T., Paquet P.C., Reimchen T.E. (2008) Spawning salmon disrupt trophic coupling between wolves and ungulate prey in coastal British Columbia. BioMed Central Ecology 8:1-12.

Darimont C.T., Reimchen T.E., Paquet P.C. (2003) Foraging behavior by gray wolves on salmon streams in coastal British Columbia. Can. J. Zool. 81:349-353.

Dau C.P. (1992) Fall migration of Pacific brant in relation to climatic conditions. Wildfowl 43:80-95.

Dau C.P. (personal communication) Email from Christian Dau, USFWS to Philip Brna, USFWS dated 01/05/2012.

Dau C.P., Mallek E.J. (2011) Aerial survey of emperor geese and other waterbirds in southwestern Alaska, Spring 2010. Unpublished, U.S. Fish and Wildlife Service. pp. 17.

Dau J.R. (2009) Units 21D, 22A, 22B, 22C, 22D, 22E, 23,24, and 26A caribou management report, in: P. Harper (Ed.), Caribou management report of survey and inventory activities 1 July 2006 - 30 June 2008, Alaska Department of Fish and Game, Juneau, AK. pp. 176-239.

Dau J.R., Cameron R.D. (1986) Effects of a road system on caribou distribution during calving. Rangifer Special Issue 1:95-101.

Davic R.D. (2003) Linking keystone species and functional groups: a new operational definition of the keystone species concept. Conservation Ecology 7:r11.

Davis J.L., Franzmann A.W. (1979) Fire-moose-caribou interrelationships: a review and assessment. Proceedings of the North American Moose Conference Workshop 15:80-118.

Davis J.L., Valkenburg P. (1991) A review of caribou population dynamics in Alaska emphasizing limiting factors, theory, and management implications, in: C. E. Butler and S. P. Mahoney (Eds.), Proceedings of the Fourth North American Caribou Workshop, 1989, Newfoundland and Labrador Wildlife Division, St. John's, Newfoundland, Canada. pp. 184-209.

Dawson W.L., Bowles J.H. (1909) The birds of Washington: a complete, scientific and popular account of the 372 species of birds found in the state, Vol. 2 Occidental Printing Co., Seattle.

DeGange A.R., Nelson J.W. (1982) Bald Eagle predation on nocturnal seabirds. Journal of Field Ornithology 53:407-409.

Des Meules P. (1964) The influence of snow on the behavior of moose. Rapport No. 3:51-73, Ministrere du tourisme, de la chasse et de la peche, Quebec.

Dewhurst D.A. (1996) *Bald Eagle nesting and reproductive success along the Pacific Coast of the Alaska Peninsula Cape Kubugakli to Cape Kumlik 10 May-1 August 1995, U.S. Fish and Wildlife Service, Alaska Peninsula/Becharof National Wildlife Refuge, King Salmon, AK.*

Dickson D.L., Balogh G., Hanlan S. (2001) *Tracking the movement of king eiders from nesting grounds on Banks Island, NWT to their molting and wintering areas using satellite telemetry. Unpublished, Canadian Wildlife Service, Edmonton, Alberta. pp. 39.*

Dodds D.G. (1960) *Food competition and range relationships of moose and snowshoe hare in Newfoundland. Journal of Wildlife Management 24:52-60.*

Dodge W.B., Winterstein S.R., Beyer D.E., Campa H. (2004) *Survival, reproduction, and movements of moose in the western peninsula of Michigan. Alces 40:71-85.*

Doerr J.G. (1983) *Home range size, movements and habitat use in two moose, Alces alces, populations in southeastern Alaska. Canadian Field-Naturalist 97:79-88.*

Dussault C., Ouellet J.P., Courtois R., Huot J., Breton L., Jolicoeur H. (2005) *Linking moose habitat selection to limiting factors. Ecography 28:619-628.*

Dzinbal K.A., Jarvis R.L. (1984) *Coastal feeding ecology of harlequin ducks in Prince William Sound, Alaska during summer, in: D.N. Nettleship, et al. (Eds.), Marine birds: their feeding ecology and commercial fisheries relationships, Canadian Wildl. Service Special Publication, Environment Canada, Ottawa. pp. 6-10.*

Dzus E.H., Gerrard J.M. (1993) *Factors influencing Bald Eagle densities in Northcentral Saskatchewan. Journal of Wildlife Management 57:771-778.*

Eastman D.S., Ritcey R. (1987) *Moose behavioral relationships and management in British Columbia. Swedish Wildlife Research Supplement 1:101-118.*

Ehrlich P.R., Dobkin D.S., Wheye D. (1988) *The birder's handbook: a field guide to the natural history of North American birds Simon & Schuster, Inc., New York, NY.*

Elphick C.S., Klima J. (2002) *Hudsonian Godwit (Limosa haemastica), No. 115, in: A. Poole and F. Gill (Eds.), The Birds of North America, Philadelphia, PA.*

Elphick C.S., Tibbitts T.L. (1998) *Greater Yellowlegs (Tringa melanoleuca), No. 355, in: A. Poole and F. Gill (Eds.), The Birds of North American, Philadelphia, PA.*

Ely C.R., Douglas D.C., Fowler A.C., Babcock C.A., Derksen D.V., Takekawa J.Y. (1997) *Migration behavior of tundra swans from the Yukon-Kuskokwim Delta, Alaska. Wilson Bulletin 109:679-692.*

Ely C.R., Fox A.D., Alisauskas R.T., Andreev A., Bromley R.G., Degtyarev A.G., Ebbinge B., Gurtovaya E.N., Kerbes R., Kondratyev A., Kostin I., Krechmar A.V., Litvin K.E., Miyabayashi Y., Mooij J.H., Oates R.M., Orthmeyer D.L., Sabano Y., Simpson S.G., Solovieva D.V., Spindler M.A., Syroechkovsky Y.V., Takekawa J.Y., Walsh A. (2005) *Circumpolar variation in morphological characteristics of Greater White-fronted Geese Anser albifrons. Bird Study 52:104-119.*

Ely C.R., Takekawa J.Y. (1996) *Geographic variation in migratory behavior of Greater White-fronted Geese (Anser albifrons). Auk 113:889-901.*

Esler D., Schmutz J.A., Jarvis R.L., Mulcahy D.M. (2000) *Winter survival of adult female harlequin ducks in relation to history of contamination by the Exxon Valdez oil spill. J. Wildl. Manage 64:839-847.*

Fall J.A., Holen D., Davis B., Krieg T., Koster D. (2006) *Subsistence harvests and uses of wild resources in Iliamna, Newhalen, Nondalton, and Port Alsworth, Alaska, 2004. Technical*

Paper No. 302, Alaska Department of Fish and Game, Division of Subsistence, Anchorage, AK. pp. 254.

Fall J.A., Schichnes J., Chythlook M., Walker R.J. (1986) Patterns of wild resource use in Dillingham: hunting and fishing in an Alaskan regional center. Technical Paper No. 135, Alaska Department of Fish and Game, Division of Subsistence, Juneau, AK.

Fancy S.G. (1983) Movements and activity budgets of caribou near oil drilling sites in the Sagavanirktok River Floodplain, Alaska. Arctic 36.

Farley S.D., Robbins C.T. (1995) Lactation, hibernation, and mass dynamics of American black bears and grizzly bears. Can. J. Zool. 73:2216-2222.

Farmer C.D., Person K., Bowyer R.T. (2006) Risk factors and mortality of black-tailed deer in a managed forest landscape. Journal of Wildlife Management 70:1403-1415.

Fernandez C.J., Buchanan B., Gill R.E., Lanctot R.B., Warnock N. (2010) Conservation plan for Dunlin with breeding populations in North America (Calidris alpina arcticola, C. a. pacifica, and C.a. hudsonia). Version 1.1, Manomet Center for Conservation Sciences, Manomet, MA.

Fischer J.B., Griffin C.B. (2000) Feeding behavior and food habits of wintering harlequin ducks at Shemya Island, Alaska. Wilson Bulletin 112:318-325.

Fitzner R.E., Gray R.H. (1994) Winter diet and weights of Barrow's and common goldeneye in southcentral Washington. Northwest Sci 68:172-177.

Follman E.H., Hechtel J.L. (1990) Bears and pipeline construction in Alaska. Arctic 43:103-109.

Forbes G.J., Theberge J.B. (1992) Importance of scavenging on moose by wolves in Algonquin Park, Ontario. Alces 28:235-241.

Forbes G.J., Theberge J.B. (1996) Response by wolves to prey variation in central Ontario. Canadian Journal of Zoology 74:1511-1520.

Fortin J.K., Farley S.D., Rode K.D., Robbins C.T. (2007) Dietary and spatial overlap amongst sympatric ursids relative to salmon use. Ursus 18:19-29.

Franson J.C., Sileo L., Thomas N.J. (1995) Causes of eagle deaths, in: E. T. LaRoe, et al. (Eds.), Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems, UDSI National Biological Service, Washington, D.C. pp. 68.

Franzmann A.W., Schwartz C.C. (1985) Moose twinning rates: a possible condition assessment. Journal of Wildlife Management 49:394-396.

Franzmann A.W., Schwartz C.C. (1986) Black bear predation on moose calves in highly productive versus marginal moose habitats on the Kenai Peninsula, Alaska. Alces 22:139-154.

Franzmann A.W., Schwartz C.C. (1998) Ecology and management of the North American moose Smithsonian Institution Press, Washington, D.C.

Franzmann A.W., Schwartz C.C. (2007) Ecology and management of the North American moose. 2nd ed. University Press of Colorado, Boulder, Colorado.

Franzmann A.W., Schwartz C.C., Peterson R.O. (1980) Moose calf mortality in summer on the Kenai Peninsula, Alaska. Journal of Wildlife Management 44:764-768.

Fraser J.D., Anthony R.G. (2010) Human disturbance and bald eagles, in: B. A. Wright and P. F. Schempf (Eds.), Bald eagles in Alaska, Hancock House Publishers, Surrey, British Columbia, Canada. pp. 306-314.

Fredrickson L.H. (2001) Steller's eider (Polysticta stelleri), No. 571, in: A. Poole and F. Gill (Eds.), The Birds of North America, Academy of Natural Sciences, Philadelphia, PA.

Fuller T.K. (1989) Population dynamics of wolves in north-central Minnesota. Wildlife
    Monographs 105:1-41.

Fuller T.K., Mech L.D., Cochrane J.F. (2003) Wolf population dynamics, in: L. D. Mech and L.
    Boitani (Eds.), Wolves: behavior, ecology, and conservation, University of Chicago
    Press, Chicago, IL. pp. 161-191.

Gabrielson I.N. (1944a) Some Alaskan Notes. Auk 61:105-130.

Gabrielson I.N. (1944b) Some Alaskan Notes. Auk 61:270-287.

Gabrielson I.N., Lincoln F.C. (1959) The birds of Alaska The Stackpole Co., Harrisburg, PA.

Garcelon D.K. (1990) Observations of aggressive interactions by Bald Eagles of known age and
    sex. Condor 92:532-534.

Garrett M.G., Watson J.W., Anthony R.G. (1993) Bald Eagle home range and habitat use in the
    lower Columbia River estuary. Journal of Wildlife Management 57:19-27.

Gasaway W.C., Boertje R.D., Grangaard D.V., Kelleyhouse D.G., Stephenson R.O., Larsen D.G.
    (1992) The role of predation in limiting moose at low densities in Alaska and Yukon and
    implications for conservation. Wildlife Monographs 120:1-59.

Gasaway W.C., Stephenson R.O., Davis J.L., Shepherd P.E.K., Burris O.E. (1983)
    Interrelationships of wolves, prey, and man in interior Alaska. Wildlife Monographs
    84:1-50.

Geist V. (1971) Mountain sheep - A study in behavior and evolution University of Chicago Press,
    Chicago, Illinois.

Gende S.M. (2010) Perspectives on the breeding biology of Bald Eagles in Southeast Alaska, in:
    B. A. Wright and P. Schempf (Eds.), Bald Eagles in Alaska, Hancock House Publishers,
    Surrey, British Columbia, Canada. pp. 95-105.

Gende S.M., Edwards R.T., Willson M.F., Wipfli M.S. (2002) Pacific salmon in aquatic and
    terrestrial ecosystems. Bioscience 52:917-928.

Gende S.M., Quinn T.P., Hilborn R., Hendry A.P., Dickerson B. (2004) Brown bears selectively
    kill salmon with higher energy content but only in habitats that facilitate choice. Oikos
    104:518-528.

Gende S.M., Quinn T.P., Willson M.F. (2001) Consumption choice by bears feeding on salmon.
    Oecologia 127:372-382.

Gende S.M., Willson M.F. (2001) Passerine densities in riparian forests of Southeast Alaska:
    potential effects of anadromous spawning salmon. Condor 103:624-629.

Gende S.M., Willson M.F., Jacobson M. (1997) Reproductive success of Bald Eagles (Haliaeetus
    leucocephalus) and its association with habitat or landscape features and weather in
    Southeast Alaska. Canadian Journal of Zoology 75:1595-1604.

Gende S.M., Willson M.F., Marston B.H., Jacobson M., Smith W.P. (1998) Bald Eagle nesting
    density and success in relation to distance from clearcut logging in Southeast Alaska.
    Biological Conservation 83:121-126.

Gerrard J.M., Gerrard P., Maher W.J., Whitfield D.W.A. (1975) Factors influencing nest site
    selection of Bald Eagles in northern Saskatchewan and Manitoba. Blue Jay 33:169-176.

Gibson D.D. (1967) Bird observations in Katmai National Monument and vicinity, 24 February
    through 1 September, 1967, National Park Service.

Gill R.E., Butler R.W., Tomkovich P.S., Mundkur T., Handel C.M. (1994) Conservation of North
    Pacific shorebirds. Transactions of the North American Wildlife and Natural Resource
    Conference 59:63-78.

Gill R.E., Handel C.M. (1981) Shorebirds of the eastern Bering Sea, in: D. W. Hood and J. A. Calder (Eds.), The Eastern Bering Sea Shelf: Oceanography and Resources, University of Washington Press, Seattle, WA. pp. 719-738.

Gill R.E., Handel C.M. (1990) The importance of subarctic intertidal habitats to shorebirds: a study of the central Yukon-Kuskokwim Delta, Alaska. Condor 92:702-725.

Gill R.E., Handel C.M., Shelton L.A. (1983) Memorial to a Black Turnstone: An example of breeding and wintering site fidelity. North American Bird Bander 8:98-101.

Gill R.E., Jorgensen P.D. (1979) A preliminary assessment of timing and migration of shorebirds along northcentral Alaska Peninsula. Studies in Avian Biology 2:113-123.

Gill R.E., Jorgensen P.D., DeGange A.R., Kust P. (1977) Annual Report: Avifaunal assessment of Nelson Lagoon, Port Moller, and Herendeen Bay, Alaska, U.S. Fish and Wildlife Service, Office of Biological Services, Anchorage, AK.

Gill R.E., King R. (1980) Trip Report - Aerial waterbird survey - Bethel to Bechevin Bay, Alaska (October 4-8, 1980). Unpublished, U.S. Fish and Wildlife Service, National Fisheries Research Center, Anchorage, AK. pp. 11.

Gill R.E., Petersen M., Handel C.M., Nelson J., DeGange A.R., Fukuyama A., Sanger G. (1978) Annual Report: Avifaunal assessment of Nelson Lagoon, Port Moller, and Herendeen Bay, Alaska - 1977, U.S. Fish and Wildlife Service, Office of Biological Services, Anchorage, AK.

Gill R.E., Petersen M.R., Jorgensen P.D. (1981) Birds of the Northcentral Alaska Peninsula, 1976-1980. Arctic 34:286-306.

Gill R.E., Piersma T., Hufford G., Servranckx R., Riegen A. (2005) Crossing the ultimate ecological barrier: evidence for an 11,000-km-long nonstop flight from Alaska to New Zealand and eastern Australia by Bar-tailed Godwits. Condor 107:1-20.

Gill R.E., Sarvis J. (1999) Distribution and numbers of shorebirds using Bristol Bay estuaries: Results of an aerial survey conducted between 2 and 5 September 1997, U.S. Geological Survey, Alaska Biological Science Center, Anchorage, AK.

Gill R.E., Tibbitts T.L. (1999) Seasonal shorebird use of intertidal habitats in Cook Inlet, Alaska. Final Report, U.S. Geological Survey, Biological Resources Division and OCS Study, MMS 99-0012, Anchorage, AK.

Gill R.E., Tibbitts T.L., Dementyev M., Kaler R. (2004) Status of the Marbled Godwit (Limosa fedoa) on BLM lands on the Alaska Peninsula, May 2004. Unpublished, Bureau of Land Management, Anchorage, AK.

Gill R.E., Tibbitts T.L., Douglas D.C., Handel C.M., Mulcahy D.M., Gottschalck J.C., Warnock N., McCaffery B.J., Battley P.F., Piersma T. (2009) Extreme endurance flights by landbirds crossing the Pacific Ocean. Proceedings of the Royal Society B 276:447-457.

Gill R.E., Tibbitts T.L., Handel C.M. Profiles of important shorebird sites in Alaska. Information and Technology Report, unpublished, U.S. Geological Survey, Alaska Science Center, Anchorage, AK.

Gill R.E., Tomkovich P.S., McCaffery B.J. (2002) Rock Sandpiper (Calidris ptilocnemis), No. 686, in: A. Poole and F. Gill (Eds.), The Birds of North America, Philadelphia, PA.

Gill R.S., Babcock C.A., Handel C.M., Butler W.I., Raveling D.G. (1997) Migration, fidelity, and use of autumn staging grounds in Alaska by Cackling Canada geese Branta canadensis minima. Wildfowl 47:43-61.

Gillingham M.P., Klein D.R. (1992) Late-winter activity patterns of moose (Alces alces gigas) in western Alaska. Canadian Journal of Zoology 70:293-299.

Gleason J.S. (2007) Mallards feeding on salmon carcasses in Alaska. Wilson J. Ornith 119:105-107.

Glenn L.P., Miller L.H. (1980) Seasonal movements of an Alaska Peninsula brown bear population. Bears - Their Biology and Management 4:307-312.

Goldstein M.I., Poe A.J., Suring L.H., Nielson R.M., McDonald T.L. (2010) Brown bear den habitat and winter recreation in south-central Alaska. Journal of Wildlife Management 74:35-42.

Gotthardt T.A., Walton K.M., Stein J.A. (2010) Archiving historic bird checklists from Southwest Alaska's national parks into eBird and Avian Knowledge Network databases. Natural Resource Data Series NPS/SWAN/NRDS-2010/085, National Park Service, Fort Collins, CO.

Grauvogel C.A. (1984) Seward Peninsula moose population identity study. Federal Aid in Wildlife Restoration, Final Report, Alaska Department of Fish and Game, Juneau, AK. pp. 93.

Griffith B., Douglas D.C., Walsh N.E., Young D.D., McCabe T.R., Russell D.E., White R.G., Cameron R.D., Whitten K.R. (2002) The Porcupine caribou herd, in: D. C. Douglas, et al. (Eds.), Arctic Refuge coastal plain terrestrial wildlife research summaries, U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD BSR-2002-0001. pp. 8-37.

Groves C., Valutis L., Vosick D., Neely B., Wheaton K., Touval J., Runnels B. (2000) Designing a geography of hope: A practitioner's handbook for ecoregional planning. 2nd ed. The Nature Conservancy, Arlington, VA.

Haines D.E., Pollock K.H. (1998) Estimating the number of active and successful Bald Eagle nests: an application of the dual frame method. Environmental and Ecological Statistics 5:245-256.

Handel C.M., Dau C.P. (1988) Seasonal occurrence of migrant Whimbrels and Bristle-thighed Curlews on the Yukon-Kuskokwim Delta, Alaska. Condor 90:782-790.

Handel C.M., Gill R.E. (2001) Black Turnstone (Arenaria melanocephala), No. 585, in: A. Poole and F. Gill (Eds.), The Birds of North America, Philadelphia, PA.

Hansen A.J. (1987) Regulation of Bald Eagle reproductive rates in Southeast Alaska. Ecology 68:1387-1392.

Hansen A.J., Boeker E.L., Hodges J.I., Cline D.R. (1984) Bald Eagles of the Chilkat Valley, Alaska: ecology, behavior, and management. Final report of the Chilkat River Cooperative Bald eagle Study, National Audubon Society and U.S. Fish and Wildlife Service, New York, NY. pp. 27.

Hansen A.J., Dyer M.I., Shugart H.H., Boeker E.L. (1986) Behavioral ecology of Bald Eagles along the Northwest Coast: A landscape perspective. ORNL/TM-9683, Oak Ridge National Laboratory, Environmental Sciences Division Publication No. 2548, Oak Ridge, TN. pp. 166.

Hansen A.J., Hodges J.I. (1985) High rates of nonbreeding adult Bald Eagles in Southeastern Alaska. Journal of Wildlife Management 49:454-458.

Hansen A.J., Stalmaster M.V., Newman J.R. (1980) Habitat characteristics, function and destruction of Bald Eagle communal roosts in western Washington, in: R. L. Knight, et al. (Eds.), Proceedings of the Washington Bald Eagle symposium, Nature Conservancy, Seattle, WA. pp. 221-229.

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Harmata A.R. (1984) Bald Eagles of San Luis Valley, Colorado: their winter ecology and spring migration, Montana State University, Bozeman, MT.

Harmata A.R., Montopoli G.J., Oakleaf B., Harmata P.J., Restani M. (1999) Movements and survival of Bald Eagles banded in the Greater Yellowstone Ecosystem. Journal of Wildlife Management 63:781-793.

Hauge T.M., Keith L.B. (1981) Dynamics of moose populations in northeast Alberta. Journal of Wildlife Management 45:573-597.

Heglund P.J. (1992) Patterns of wetland use among aquatic birds in the interior boreal forest region of Alaska, Univ. Missouri, Columbia. pp. 394.

Helfield J.M. (2001) Interactions of salmon, bear, and riparian vegetation in Alaska, University of Washington. pp. 92 pgs.

Helfield J.M., Naiman R.J. (2001) Effects of salmon-derived nitrogen on riparian forest growth and implications for stream productivity. Ecology 82:2403-2409.

Helfield J.M., Naiman R.J. (2006) Keystone interactions: salmon and bear in riparian forests of Alaska. Ecosystems 9:167-180.

Herrero S. (2002) Bear attacks: their causes and avoidance. 2nd ed. Globe Pequot Press, Guilford, Connecticut.

Herrero S., Higgins A. (1999) Human injuries inflicted by bears in British Columbia: 1960-1997. Ursus 11:209-218.

Herrero S., Higgins A. (2003) Human injuries inflicted by bears in Alberta: 1960-1998. Ursus 14:44-54.

Herrero S., Smith T., Debruyn T.D., Gunther K., Matt C.A. (2005) Brown bear habituation to people - safety, risks, and benefits. Wildlife Society Bulletin 33:362-373.

Hilborn R., Quinn T.P., Schindler D.E., Rogers D.E. (2003) Biocomplexity and fisheries sustainability. Proc. Nation. Acad. Sci. 100:6564-6568.

Hilderbrand G. (personal communication) Email from Grant Hilderbrand, NPS to Guy Adema, NPS dated 01/04/2012.

Hilderbrand G.V., Farley S.D., Robbins C.T. (1998) Predicting the body condition of bears via two field methods. Journal of Wildlife Management 62:406-409.

Hilderbrand G.V., Farley S.D., Schwartz C.C., Robbins C.T. (2004) Importance of salmon to wildlife: implications for integrated management. Ursus 15:1-9.

Hilderbrand G.V., Hanley T.A., Robbins C.T., Schwartz C.C. (1999a) Role of brown bears (Ursus arctos) in the flow of marine nitrogen into a terrestrial ecosystem. Oecologia 121:546-550.

Hilderbrand G.V., Jenkins S.G., Schwartz C.C., Hanley T.A., Robbins C.T. (1999b) Effect of seasonal differences in dietary meat intake on changes in body mass and composition in wild and captive brown bears. Can. J. Zool. 77:1623-1630.

Hilderbrand G.V., Schwartz C.C., Robbins C.T., Hanley T.A. (2000) Effect of hibernation and reproductive status on body mass and condition of coastal brown bears. Journal of Wildlife Management 64:178-183.

Hilderbrand G.V., Schwartz C.C., Robbins C.T., Jacoby M.E., Hanley T.A., Arthur S.M., Servheen C. (1999c) The importance of meat, particularly salmon, to body size, population productivity, and conservation of North American brown bears. Can. J. Zool. 77:132-138.

Hinkes M.T., Collins G.H., Van Daele L.J., Kovach S.D., Aderman A.R., Woolington J.D., Seavoy R.J. (2005) Influence of population growth on caribou herd identity, calving ground fidelity, and behavior. Journal of Wildlife Management 69:1147-1162.

Hinkes M.T., Van Daele L.J. (1996) Population growth and status of the Nushagak Peninsula caribou herd in southwest Alaska following reintroduction, 1988-1993. Rangifer Special Issue 9:301-310.

Hodges J.I. (1979) Southeast Alaska mainland river Bald Eagle nest survey, U.S. Fish and Wildlife Service, Juneau, AK.

Hodges J.I. (2011) Bald Eagle population surveys of the north Pacific Ocean, 1967-2010. Northwestern Naturalist 92:7-12.

Hodges J.I., Eldridge W.D. (2001) Aerial surveys of eiders and other waterbirds on the eastern Arctic coast of Russia. Wildfowl 52:127-142.

Hodges J.I., King J.G., Conant B., Hansen H.A. (1996) Aerial surveys of waterbirds in Alaska 1957-94: population trends and observer variability. Information and Technology Report No. 4, U.S. National Biological Service.

Hodges J.I., Robards F.C. (1982) Observations of 3,850 Bald Eagle nests in Southeast Alaska, in: W. N. Ladd and P. F. Schempf (Eds.), Raptor management and biology in Alaska and Western Canada: Proceedings of a symposium and workshop held February 17-20, 1981, U.S. Fish and Wildlife Service, Anchorage, AK. pp. 37-46.

Hoffman R.R. (1973) The ruminant stomach. East African Monograph in Biology, East African Literature Bureau, Nairobi, Africa. pp. 54.

Hofmann R.R. (1989) Evolutionary steps of ecophysiological adaptation and diversification of ruminants: a comparative view of their digestive system. Oecologia 78:443-457.

Holl K.D., Cairns J. (1995) Landscape indicators in ecotoxicology, in: D. J. Hoffman, et al. (Eds.), Handbook of Ecotoxicology, Lewis Publishers, Boca Raton, FL. pp. 185-197.

Holtgrieve G.W. (2009) Linking species to ecosystems: effects of spawning salmon on aquatic ecosystem function in Bristol Bay, Alaska, University of Washington. pp. 169 pgs.

Homer C.C., Huang L., Yang B., Wylie B., Coan M. (2004) Development of a 2001 National Land Cover Database for the United States. Photogrammetric Engineering and Remote Sensing 70:829-840.

Hotchkiss L.A. (1989) 1988-1989 annual progress report of the caribou reintroduction project on the Togiak National Wildlife Refuge, Dillingham, Alaska, Togiak National Wildlife Refuge, Dillingham, Alaska. pp. 8.

Houle M., Fortin D., Dussault C., Courtois R., Ouellet J.-P. (2010) Cumulative effects of forestry on habitat use by gray wolf (Canis lupus) in the boreal forest. Landscape Ecology 25:419-433.

Houston D.B. (1968) The Shiras moose in Jackson Hole, Wyoming. Technical Bulletin 1, Grand Teton National Historic Association. pp. 110.

Hundertmark K.J. (2007) Home range, dispersal, and migration, in: A. W. Franzmann and C. C. Schwartz (Eds.), Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 303-336.

Hundertmark K.J., Bowyer R.T., Shields G.F., Schwartz C.C. (2003) Mitochondrial phylogeography of moose (Alces alces) in North America. Journal Of Mammalogy 84:718-728.

Hurley J.B. (1931a) Birds observed in the Bristol Bay Region, Alaska (Part I). Murrelet 12:7-11.

Hurley J.B. (1931b) Birds observed in the Bristol Bay Region, Alaska (Part II). Murrelet 12:35-42.

Hurley J.B. (1931c) Birds observed in the Bristol Bay Region, Alaska (Part III). Murrelet 12:71-75.

Hurley J.B. (1932) Birds observed in the Bristol Bay Region, Alaska (Part IV). Murrelet 13:16-21.

Imler R.H., Kalmbach E.R. (1955) The Bald Eagle and its economic status, U.S. Fish and Wildlife Service Circular 30.

Isleib M.E. (1979) Migratory shorebird populations on the Copper River Delta and eastern Prince William Sound, Alaska. Studies in Avian Biology 2:125-129.

Isleib M.E. (2010) Avian resources of Southeast Alaska: a brief review and their importance to eagles, in: B. A. Wright and P. Schempf (Eds.), Bald Eagles in Alaska, Hancock House Publishers, Surrey, British Columbia, Canada. pp. 68-71.

Isleib M.E., Kessel B. (1973) Birds of the North Gulf Coast-Prince William Sound Region, Alaska. Univ. Alaska Biol. Papers 14.

Iverson G.C., Warnock S.E., Butler R.W., Bishop M.A., Warnock N. (1996) Spring migration of Western Sandpipers along the Pacific Coast of North America: a telemetry study. Condor 98:10-21.

Iwata T., Nakano S., Murakami M. (2003) Stream meanders increase insectivorous bird abundance in riparian deciduous forests. Ecography 26:325-337.

James A.R.C., Boutin S., Hebert D.M., Rippin A.B. (2004) Spatial separation of caribou from moose and its relation to predation by wolves. Journal of Wildlife Management 68:799-809.

Jarrell G.H., MacDonald A.O., Cook J.A. (2004) Checklist to the Mammals of Alaska, University of Alaska Museum, Fairbanks, AK.

Jarvis R.L., Noyes J.H. (1986) Foods of canvasbacks and redheads in Nevada: paired males and ducklings. J. Wildl. Manage 50:199-203.

Jenkins J.M., Jackman R.E. (1993) Mate and nest site fidelity in a resident population of Bald Eagles. Condor 95:1053-1056.

Jenkins J.M., Jackman R.E. (1994) Field experiments in prey selection by resident Bald Eagles in the breeding and non-breeding season. Journal of Field Ornithology 65:441-446.

Jensen K.T., Kristensen L.D. (1990) A field experiment on competition between Corophium volutator (Pallas) and Corophium arenarium Crawford (Crustacea: Amphipoda): effects on survival, reproduction and recruitment. Journal of Experimental Marine Biology and Ecology 137:1-24.

Johnson J., Blanche P. (2011) Catalog of waters important for spawning, rearing, or migration of anadromous fishes - Southwestern Region, Effective June 1, 2011, Special Publication No. 11-08, Alaska Department of Fish and Game, Anchorage, AK.

Johnson O.W., Adler C.D., Ayres L.A., Bishop M.A., Doster J.E., Johnson P.M., Kienholz R.J., Savage S.E. (2004) Radio-tagged Pacific Golden-Plovers: further insight concerning the Hawaii-Alaska migratory link. Wilson Bulletin 116:158-162.

Johnson O.W., Bennett A.J., Alsworth L., Bennett L.A., Johnson P.M., Morgart J.R., Kienholz R.J. (2001) Radio-tagging Pacific Golden-Plovers: the Hawaii-Alaska link, spring destinations, and breeding season survival. Journal of Field Ornithology 72:537-546.

Johnson O.W., Connors P.G. (1996) American Golden-Plover (Pluvialis dominica), Pacific Golden-Plover (Pluvialis fulva), No. 201-202, in: A. Poole and F. Gill (Eds.), The Birds of North America, Academy of Natural Sciences, Philadelphia, PA.

Johnson O.W., Fielding L., Fox J.W., Gold R.S., Goodwill R.H., Johnson P.M. (2011) Tracking the migrations of Pacific Golden-Plovers (Pluvialis fulva) between Hawaii and Alaska: new insight on flight performance, breeding ground destinations, and nesting from birds carrying light level geolocators. Wader Study Group Bulletin 118:26-31.

Johnson O.W., Goodwill R.H., Bruner A.E., Johnson P.M., Gold R.S., Utzurrum R.B., Seamon J.O. (2008) Pacific Golden-Plover Pluvialis fulva in American Samoa: spring migration, fall return of marked birds, and other observations. Wader Study Group Bulletin 115:20-23.

Jones J.J., Drobney R.D. (1986) Winter feeding ecology of scaup and common goldeneye in Michigan. J. Wildl. Manage 50:446-452.

Jordan P.A. (1987) Aquatic forage and the sodium ecology of moose: a review. Swedish Wildlife Research Supplement 1:119-137.

Joyal R. (1987) Moose habitat investigations in Quebec and management implications. Swedish Wildlife Research Supplement 1:139-152.

Karns P. (2007) Population distribution, density, and trends, in: A. W. Franzmann and C. C. Schwartz (Eds.), Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 125-140.

Keech M.A., Lindberg M.S., Boertje R.D., Valkenburg P., Taras B.D., Boudreau T.A., Beckmen K.B. (2011) Effects of predator treatments, individual traits, and environment on moose survival in Alaska. Journal of Wildlife Management 75:1361-1380.

Kelsall J.P. (1969) Structural adaptations of moose and deer for snow. Journal Of Mammalogy 50:302-310.

Kelsall J.P., Prescott W. (1971) Moose and deer behavior in snow. Report Series 15, Canadian Wildlife Service, Ottawa, Canada. pp. 27.

Kelsall J.P., Telfer E.S. (1974) Biogeography of moose with particular reference to western North America. Naturaliste Canada (Quebec) 101:117-130.

Kelsall J.P., Telfer E.S., Wright T.D. (1977) The effects of fire on the ecology of the boreal forest, with particular reference to the Canadian north: a review and selected bibliography. Occasional Paper 323, Canadian Wildlife Service, Ottawa, Canada.

Kertell K. (1991) Disappearance of the Steller's eider from the Yukon-Kuskokwim Delta, Alaska. Arctic 44:177-187.

Kessel B. (1998) Habitat characteristics of some passerine birds in Western North American taiga University of Alaska Press, Fairbanks, AK.

Kessel B., Rocque D.A., Barclay J.S. (2002) Greater Scaup (Aythya marila). The Birds of North America Online, in: A. Poole (Ed.), Cornell Lab of Ornithology, Ithaca, NY.

King J.G. (1973) A cosmopolitian duck moulting resort; Takslesluk Lake Alaska. Wildfowl 24:103-109.

King J.G. (1982) Crossroads for migration, Alaska Fish Tails and Game Trails. pp. 11-12.

King J.G. (2010) The Bald Eagle in American culture, in: B. A. Wright and P. Schempf (Eds.), Bald Eagles in Alaska, Hancock House Publishers, Surrey, British Columbia, Canada. pp. 25-29.

King J.G., Lensink C.J. (1971) An evaluation of Alaskan habitat for migratory birds. Unpublished, Bureau of Sport Fisheries and Wildlife, Washington, D.C. pp. 74.

King J.G., McKnight D.E. (1969) A waterbird survey in Bristol Bay and proposals for future studies. Unpublished, U.S. Fish and Wildlife Service, Juneau, AK. pp. 11.

King R.J., Dau C.P. (1992) Spring population survey of emperor geese (Chen canagica) in southwestern Alaska 30 April-7 May, 1992. Unpublished, U.S. Fish and Wildlife Service, Fairbanks, AK. pp. 32.

Kistchinski A.A. (1968) Birds of the Kolyma Highlands Moscow (In Russian with English summary).

Klaassen M., Abraham K.F., Jefferies R.L., Vrtiska M. (2006) Factors affecting the site of investment and the reliance on savings for arctic breeders: the capital-income dichotomy revisited. Ardea. 94:371-384.

Kline T.C., Goering J.J., Mathisen O.A., Poe P.H., Parker P.L., Scalan R.S. (1993) Recycling of elements transported upstream by runs of Pacific salmon: II. ^{15}N and ^{13}C evidence in the Kvichak River watershed, Bristol Bay, Southwestern Alaska. Can. J. Fish. Aquat. Sci. 50:2350-2365.

Knight R.L., Randolph P.J., Allen G.T., Young L.S., Wigen R.J. (1990) Diets of nesting Bald Eagles, Haliaeetus leucocephalus, in western Washington. Canadian Field-Naturalist 104:545-551.

Knight R.L., Skagen S.K. (1988) Agonistic asymmetries and the foraging ecology of Bald Eagles. Ecology 69:1188-1194.

Knight S.K., Knight R.L. (1983) Aspects of food finding by wintering Bald Eagles. Auk 100:477-484.

Kohira M., Rexstad E.A. (1995) Diets of wolves, Canis lupus, in logged and unlogged forests of southeastern Alaska. Canadian Field-Naturalist 111:429-435.

Kohira M., Rexstad E.A. (1997) Diets of wolves, Canis lupus, in logged and unlogged forests of southeastern Alaska. Canadian Field-Naturalist 111:429-435.

Kovach S.D., Collins G.H., Hinkes M.T., Denton J.W. (2006) Reproduction and survival of brown bears in southwest Alaska, USA. Ursus 17:16-29.

Kralovec M.L. (1994) Bald Eagle movements in and from Glacier Bay National Park and Preserve, National Park Service, Glacier Bay National Park, Gustavus, AK.

Kuyt E., Johnson B.E., Drewien R.C. (1981) A wolf kills a juvenile whooping crane. Blue Jay 392:116-119.

Lack D. (1954) The natural regulation of animal numbers Oxford, London.

Lanctot R., Goatcher B., Scribner K., Talbot S., Pierson B., Esler D., Zwiefelhofer D. (1999) Harlequin duck recovery from the Exxon Valdez oil spill: a population genetics perspective. Auk 116:781-791.

Lanctot R.B., Sandercock B.K., Kempenaers B. (2000) Do male breeding displays function to attract mates or defend territories? The explanatory role of mate and site fidelity. Waterbirds 23:155-164.

Larkin G.A., Slaney P.A. (1997) Implications of trends in marine-derived nutrient influx to South Coastal British Columbia salmonid production. Fisheries 22:16-24.

Larned W.L., Bollinger K.S. (2011) Steller's Eider spring migration surveys, Southwest Alaska 2010. Unpublished, U.S. Fish and Wildlife Service, Anchorage, AK. pp. 26.

Larned W.W. (2008) Steller's eider spring migration survey, Southwest Alaska. Unpublished, U.S. Fish and Wildlife Service, Anchorage, AK. pp. 24.

Larned W.W., Tiplady T. (1998) Aerial surveys to evaluate King Eider molting areas detected by satellite telemetry in western Alaska. Unpublished, U.S. Fish and Wildlife Service, Anchorage, AK. pp. 9.

Larsen D.G., Gauthier D.A., Markel R.L. (1989) Causes and rates of moose mortality in the southwest Yukon. Journal of Wildlife Management 53:548-557.

Leighton F.A., Gerrard J.M., Gerrard P., Whitfield D.W.A., Maher W.J. (1979) An aerial census of Bald Eagles in Saskatchewan. Journal of Wildlife Management 43:61-69.

LeResche R.E. (1974) Moose migration in North America. Naturaliste Canada (Quebec) 101:393-415.

LeResche R.E., Bishop R.H., Coady J.W. (1974) Distribution and habitats of moose in Alaska. Le Naturaliste Canadien 101:143-178.

Lewis S. (personal communication) Telephone conversation between S. Lewis, USFWS and Maureen De Zeeuw, USFWS dated 08/11/2011.

Limpert R.J., Earnst S.L. (1994.) Tundra Swan (Cygnus columbianus), in: A. P. a. F. Gill (Ed.), The Birds of North America, The Academy of Natural Sciences, and American Ornithologists' Union, Philadelphia, and Washington, D.C.

Lindstrom A., Gill R.E., Jamieson S.E., McCaffery B.J., Wennerberg L., Wikelski M., Klaassen M. (2011) A puzzling migratory detour: are fueling conditions in Alaska driving the movement of juvenile Sharp-tailed Sandpipers? Condor 113:129-139.

Livingston S.A., Todd C.S., Krohn W.B., Owen R.B. (1990) Habitat models for nesting Bald Eagles in Maine. Journal of Wildlife Management 54:644-653.

Lok E.K., Esler D., Takekawa J.Y., DeLaCruz S.W., Boyd W.S., Nysewander D.R., Evenson J.R., Ward D.H. (2011) Stopover habitats of spring migrating surf scoters in southeast Alaska. J. Wildl. Manage 75:92-100.

Lok E.K., Kirk M., Esler D., Boyd W.S. (2008) Movements of pre-migratory surf and white-winged scoters in response to Pacific herring spawn. Waterbirds 31:385-393.

Lynch G.M., Morgantini L.E. (1984) Sex and age differential in seasonal home range of moose in northwestern Alberta. Alces 20:61-78.

MacCracken J.G., Van Ballenberghe V., Peek J.M. (1993) Use of aquatic plants by moose - sodium hunger or foraging efficiency. Canadian Journal of Zoology 71:2345-2351.

MacCracken J.G., Van Ballenberghe V., Peek J.M. (1997a) Habitat relationships of moose on the Copper River Delta in coastal south-central Alaska. Wildlife Monographs 136:1-52.

MacCracken J.G., Van Ballenberghe V., Peek J.M. (1997b) Habitat relationships of moose on the Copper River Delta in coastal south-central Alaska. Wildlife Monographs 136:3-52.

MacDonald R. (2000) Late summer occurrence of shorebirds on the Southern Nushagak Peninsula, Alaska, 2000, U.S. Fish and Wildlife Service, Togiak National Wildlife Refuge, Dillingham, AK.

MacDonald R. (2006) Occupancy and productivity of nesting Bald Eagles, Togiak National Wildlife Refuge, Alaska, 2006, U.S. Fish and Wildlife Service, Togiak National Wildlife Refuge, Dillingham, AK. pp. 10.

MacDonald R., Wachtel J. (1999) Staging and migration of shorebirds along the Nushagak Peninsula, Bristol Bay, Alaska - Fall 1999. Unpublished report, U.S. Fish and Wildlife Service, Togiak National Wildlife Refuge, Dillingham, AK. pp. 18.

Mahaffy M.S., Frenzel L.D. (1987) Elicited territorial responses of northern Bald Eagles near active nests. Journal of Wildlife Management 51:551-554.

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Maier J.A.K., Ver Hoef J.M., McGuire A.D., Bowyer R.T., Saperstein L., Maier H.A. (2005) Distribution and density of moose in relation to landscape characteristics: effects of scale. Canadian Journal of Forest Research 35:2233-2243.

Mallek E.J., Dau C.P. (2004) Aerial survey of Emperor Geese and other waterbirds in Southwestern Alaska, Fall 2004, U.S. Fish and Wildlife Service, Migratory Bird Management, Fairbanks, AK.

Mallek E.J., Dau C.P. (2011) Aerial survey of Emperor Geese and other waterbirds in Southwestern Alaska, Fall 2010, U.S. Fish and Wildlife Service, Migratory Bird Management, Fairbanks, AK. pp. 14.

Mallek E.J., Groves D.J. (2010) Alaska-Yukon waterfowl breeding population survey. Unpublished, U.S. Fish and Wildlife Service, Fairbanks and Juneau, AK. pp. 30.

Mangipane B.M. (2010) Bald Eagle nest survey in Lake Clark National Park and Preserve, Alaska. Natural Resource Data Series NPS/LACL/NRDS-2010/XXX, National Park Service, Fort Collins, Colorado.

Mangipane B.M. (personal communication) Email from B. Mangipane, NPS to Phil Brna, USFWS dated 09/27/2011.

Markgren G. (1969) Reproduction of moose in Sweden. Viltrevy 6:127-299.

Matt C.A. (2010) Third international bear-people conflicts workshop summary, Red Deer College, Calgary, Alberta, Canada.

Mattson D.J., Blanchard B.M., Knight R.D. (1992) Yellowstone grizzly bear mortality, human habituation, and whitebark pine seed crops. Journal of Wildlife Management 56:432-442.

McArt S.H., Spalinger D.E., Collins W.B., Schoen E.R., Stevenson T., Bucho M. (2009) Summer dietary nitrogen availability as a potential bottom-up constraint on moose in south-central Alaska. Ecology 90:1400-1411.

McClelland B.R., Young L.S., Shea D.S., McClelland P.T., Allen H.L., Spettigue E.B. (1982) The Bald Eagle concentration in Glacier National Park, Montana: origin, growth and variation in numbers. Living Bird 19:133-155.

McClelland R., McClelland P. (1986) Bald Eagles and Kokanee salmon: a rendezvous in Glacier National Park. Western Wildlands 11:7-11.

McLoughlin P.D., Case R.L., Gau R.J., Ferguson S.H., Messier F. (1999) Annual and seasonal movement patterns of barren-ground grizzly bears in the central Northwest Territories. Ursus 11:79-86.

McLoughlin P.D., Ferguson S.H., Messier F. (2000) Intraspecific variation in home range overlap with habitat quality: a comparison among brown bear populations. Evolutionary Ecology 14:39-60.

McLoughlin P.D., Walton K.M., Cluff H.D., Pacquet P.C., Ramsay M.A. (2004) Hierarchal habitat selection by tundra wolves. Journal Of Mammalogy 85:576-580.

Mech D. (1970) The Wolf: The ecology and behavior of an endangered species American Museum of Natural History, Garden City, NY.

Mech L.D. (1977) Productivity, mortality, and population trends of wolves in northeastern Minnesota. Journal Of Mammalogy 58:559-574.

Mech L.D. (1988) The arctic wolf: Living with the pack Voyageur Press, Stillwater, MN.

Mech L.D. (1994) Regular and homeward travel speeds of arctic wolves. Journal Of Mammalogy 75:741-742.

Mech L.D. (1995) The challenge and opportunity of recovering wolf populations. Conservation Biology 9:270-278.

Mech L.D., Adams L.G., Meier T.J., Burch J.W., Dale B.W. (1998) The wolves of Denali University of Minnesota Press, Minneapolis, Minnesota.

Mech L.D., Boitani L. (2003) Wolf social ecology, in: L. D. Mech and L. Boitani (Editors) (Eds.), Wolves: behavior, ecology, and conservation, University of Chicago Press,, Chicago, USA. pp. 1-34.

Mech L.D., Peterson R.O. (2003) Wolf-prey relations, in: L. D. Mech and L. B. (Editors) (Eds.), Wolves: behavior, ecology, and conservation, University of Chicago Press, Chicago, USA. pp. 131-160.

Meier T.J., Burch J.W., Mech L.D., Adams L.D. (1995) Pack structure dynamics and genetic relatedness among wolf packs in a naturally regulated population, in: L. N. Carbyn, et al. (Eds.), Ecology and conservation of wolves in a changing world, Canadian Circumpolar Institute, Edmonton, Alberta. pp. 293-302.

Messier F. (1985) Solitary living and extraterritorial movements of wolves in relation to social status and prey abundance. Canadian Journal of Zoology 63:239-245.

Michel J., Domeracki D.D., Thebeau L.C., Getter C.D., Hayes M.O. (1982) Sensitivity of coastal environments and wildlife to spilled oil of the Bristol Bay area of the Bering Sea, Alaska, Research Planning Institute, Inc, Columbia, SC. pp. 117.

Miller B.K., Litvatitis J.A. (1992) Habitat segregation by moose in a boreal forest ecotone. Acta Theriological 37:41-50.

Miller G.S. (1899) A new moose from Alaska. Proceedings of Biological Society of Washington 13:57-59.

Miller S.D. (1990) Denning ecology of brown bears in southcentral Alaska and comparisons with a sympatric black bear population. Int. Conf. Bear Res. and Manage. 8:279-287.

Miller S.D., Sellers R.A. (1992) Brown bear density on the Alaska Peninsula at Black Lake. Report on cooperative interagency brown bear studies on the Alaska Peninsula, Alaska Department of Fish and Game, Juneau, AK. pp. 57.

Miller S.D., Sellers R.A., Keay J.A. (2003) Effects of hunting on brown bear cub survival and litter size in Alaska. Ursus 14:130-152.

Miller S.D., White G.C., Sellers R.A., Reynolds H.V., Schoen J.W., Titus K., Barnes V.G. (1997) Brown and black bear density estimation in Alaska using radiotelemetry and replicated mark-resight techniques. Wildlife Monographs 133:1-55.

Miquelle D.G., Peek J.M., Van Ballenberghe V. (1992) Sexual segregation in Alaskan moose. Wildlife Monographs 122:1-57.

Miquelle D.G., Van Ballenberghe V. (1989) Impact of bark stripping by moose on aspen-spruce communities. Journal of Wildlife Management 53:577-586.

Mitchell C.D., Eichholz M.W. (2010) Trumpeter swan (Cygnus buccinator). , in: A. Poole (Ed.), The birds of North America online, Cornell Lab of Ornithology, Ithaca, NY.

Mladenoff D.J., Sickley T.A., Haight R.G., Wydeven A.P. (1995) A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes region. Conservation Biology 9:279-294.

Mladenoff D.J., Sickley T.A., Wydeven A.P. (1999) Predicting gray wolf landscape recolonization: Logistic regression models vs. new field data. Ecological Applications 9:37-44.

Modafferi R.D. (1991) Train-moose kills in Alaska: characteristics and relationships with snowpack depth and moose distribution in Lower Susitna Valley. Alces 27:193-207.

Molvar E.M., Bowyer R.T. (1994) Costs and benefits of group living in a recently social ungulate: the Alaskan moose. Journal Of Mammalogy 75:621-630.

Molvar E.M., Bowyer R.T., Van Ballenberghe V. (1993) Moose herbivory, browse quality, and nutrient cycling in an Alaskan treeline community. Oecologia 94:472-479.

Moore J.W., Schindler D.E. (2004) Nutrient export from freshwater ecosystems by anadromous sockeye salmon (Oncorhynchus nerka). Can. J. Fish. Aquat. Sci. 61:1582-1589.

Morrison R.I.G., McCaffery B.J., Gill R.E., Skagen S.K., Jones S.L., Page G.W., Gratto-Trevor C.L., Andres B.A. (2006) Population estimates of North American shorebirds, 2006. Wader Study Group Bulletin 111:67-85.

Morrissey C.A., Elliott J.E., Ormerod S.J. (2010) Diet shifts during egg laying: implications for measuring contaminants in bird eggs. Environmental Pollution 158:447-454.

Munro J.A. (1923) A preliminary report on the relation of various ducks and gulls to the propagation of sock-eye salmon at Henderson Lake, Vancouver Island, B.C. Can. Field-Nat. 37:107-116.

Munro J.A. (1941) Studies of waterfowl in British Columbia: greater scaup duck, lesser scaup duck. Canadian J. Research 19d:113-138.

Munro J.A. (1942) Studies of waterfowl in British Columbia: buffle-head. Canadian J. Research 20d:133-160.

Munro J.A. (1943) Studies of waterfowl in British Columbia: mallard. Canadian J. Research 21d:223-260.

Munro J.A., Clemens W.A. (1931) Waterfowl in relation to the spawning of herring in British Columbia. Biol. Board of Canada Bull No. 17.

Munro J.A., Clemens W.A. (1932) Food of the American merganser (Mergus merganser americanus) in British Columbia: a preliminary paper. Can. Field-Nat. 46.

Munro J.A., Clemens W.A. (1937) The American merganser in British Columbia and its relation to the fish population. Biol. Board Canada Bull 55.

Munro J.A., Clemens W.A. (1939) The food and feeding habits of the red-breasted merganser in British Columbia. J. Wildl. Manage 3:46-53.

Murakami M., Nakano S. (2001) Species-specific foraging behavior of birds in a riparian forest. Ecological Research 16:913-923.

Murakami M., Nakano S. (2002) Indirect effect of aquatic insect emergence on a terrestrial insect population through by birds predation. Ecology Letters 5:333-337.

Naiman R.J., Bilby R.E., Schindler D., Helfield J.M. (2002a) Pacific salmon, nutrients, and the dynamics of freshwater and riparian ecosystems. Ecosystems 5:399-417.

Naiman R.J., Bilby R.E., Schindler D.E., Helfield J.M. (2002b) Pacific salmon, nutrients, and the dynamics of freshwater and riparian ecosystems. Ecosystems 5:299-417.

Nakano S., Murakami M. (2001) Reciprocal subsidies: dynamic interdependence between terrestrial and aquatic food webs. PNAS 98:166-170.

National Park Service. (2011) Bird List - Lake Clark National Park and Preserve.

National Research Council. (1997) Wolves, bears, and their prey in Alaska National Academy Press, Washington D.C.

Naves L.C. (2010a) Alaska migratory bird subsistence harvest estimates 2004-2007, Alaska Migratory Bird Co-Management Council. Technical Paper No. 349, Alaska Department of Fish and Game, Division of Subsistence, Anchorage, AK. pp. 182.

Naves L.C. (2010b) *Alaska migratory bird subsistence harvest estimates 2008, Alaska Migratory Bird Co-Management Council. Technical Paper No. 353, Alaska Department of Fish and Game, Division of Subsistence, Anchorage, AK. pp. 64.*

Naves L.C. (2011) *Alaska migratory bird subsistence harvest estimates, 2009, Alaska Migratory Birds Co-Management Council Technical Paper No 364., Alaska Department of Fish and Game, Division of Subsistence, Anchorage, AK. pp. 64pp + Appendices.*

Nellemann C., Vistnes I., Jordhoy P., Strand O. (2001) *Winter distribution of wild reindeer in relation to power lines, roads and resorts. Biological Conservation 101:351-360.*

Nellemann C., Vistnes I., Jordhoy P., Strand O., Newton A. (2003) *Progressive impact of piecemeal infrastructure development on wild reindeer. Biological Conservation 113:307-317.*

Nettleship D.N. (2000) *Ruddy Turnstone (Arenaria interpres), No. 537, in: A. Poole and F. Gill (Eds.), The Birds of North America, Academy of Natural Sciences, Philadelphia, PA.*

Norton D.W., Senner S.E., Gill R.E., Martin P.D., Wright J.M., Fukuyama A.K. (1990) *Shorebirds and herring roe in Prince William Sound, Alaska. American Birds 44:367-371,508.*

Nowacki G., Spencer P., Fleming M., Brock T., Jorgenson T. (2001) *Ecoregions of Alaska, U.S. Geological Survey Open-File Report 02-297 (map).*

Nushagak-Mulchatna Watershed Council. (2007) *Nushagak River Watershed Traditional Use Area Conservation Plan, Bristol Bay Native Association, Dillingham, AK.*

Obermeyer K.E., White K.S., Willson M.F. (2006) *Influence of salmon on the nesting ecology of American Dippers in Southeastern Alaska. Northwest Science 80:26-33.*

Odum E.P. (1983) *Fundamentals of Ecology. 3rd ed. CBS College Publications, New York, NY.*

Oehlers S.A., Bowyer R.T., Huettmann F., Person D.K., Kessler W.B. (2011) *Sex and scale: implications for habitat selection by Alaskan moose Alces alces gigas. Wildlife Biology 17:67-84.*

Oldemeyer J.L., Franzmann A.W., Brundage A.L., Arneso P.D., Flynn A. (1977) *Browse quality and the Kenai moose population. Journal of Wildlife Management 41:533-542.*

Oldemeyer J.L., Regelin W.L. (1987) *Forest succession, habitat management, and moose on the Kenai National Wildlife Refuge. Swedish Wildlife Research Supplement 1:163-179.*

Oppel S., Powell A.N., Dickson D.L. (2008) *Timing and distance of King Eider migration and winter movements. Condor 110:296-305.*

Orthmeyer D.L., Takekawa J.Y., Ely C.R., Wege M.L., Newton W.E. (1995) *Morphological variation in Greater White-fronted Geese in the Pacific Flyway. Condor 97:123-132.*

Osborne T.O., Paragi T.F., Bodkin J.L., Loranger A.J., Johnson W.N. (1991) *Extent, causes, and timing of moose calf mortality in western interior Alaska. Alces 27:24-30.*

Osgood W.H. (1904) *A biological reconnaissance of the base of the Alaska Peninsula. North American Fauna No. 24, U.S. Fish and Wildlife Service, Washington, D.C.*

Oyler-McCance S.J., Ransler F.A., Berkman L.K., Quinn T.W. (2007) *A rangewide population genetics study of trumpeter swans. Conserv. Genetics 8:1339-1353.*

Pacific Flyway Council. (1994) *Pacific Flyway management plan for the Pacific population of Lesser Canada Geese. Unpublished draft report, Lesser/Taverner's Canada Goose Subcommittee, Pacific Flyway Study Committee, c/o U.S. Fish and Wildlife Service, Portland, OR. pp. 27.*

Pacific Flyway Council. (1999) Pacific Flyway management plan for the Cackling Canada Goose. Unpublished, Cackling Canada Goose Subcommittee, Pacific Flyway Study Committee, c/o U.S. Fish and Wildlife Service, Portland, OR. pp. 36.

Pacific Flyway Council. (2001) Pacific Flyway management plan for the western population of Tundra Swans, Subcommittee on Tundra Swans, Pacific Flyway Study Committee, c/o U.S. Fish and Wildlife Service, Portland, OR. pp. 28.

Pacific Flyway Council. (2002) Pacific Flyway management plan for Pacific Brant. Unpublished, Pacific Flyway Study Committee, c/o U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Portland, OR. pp. 40.

Pacific Flyway Council. (2003) Pacific Flyway management plan for the Greater White-fronted Goose. Unpublished, Greater White-fronted Goose Subcommittee, Pacific Flyway Study Committee c/o U.S. Fish and Wildlife Service, Portland, OR. pp. 27.

Pacific Flyway Council. (2006) Pacific Flyway management plan for the Emperor Goose. Unpublished, Emperor Goose Subcommittee, Pacific Flyway Study Committee, c/o U.S. Fish and Wildlife Service, Portland, OR. pp. 24.

Pacific Flyway Council. (2008) Pacific Flyway management plan for the Pacific Coast population of trumpeter swans, Pacific Flyway Study Commission, Unpublished Report.

Packard J.M. (2003) Wolf behavior: reproductive, social and intelligent, in: L. D. Mech and L. B. (Editors) (Eds.), Wolves: behavior, ecology, and conservation, University of Chicago Press, Chicago, USA. pp. 35-65.

Paine R. (1995) A conversation on refining the concept of keystone species. Conservation Biology 9:962-964.

Pamplin W.L. (1986) Cooperative efforts to halt population declines of geese nesting on Alaska's Yukon-Kuskokwim Delta. Transactions of the North American Wildlife and Natural Resource Conference 51:487-506.

Paquet P.C., Carbyn L.N. (2003) Gray wolf, in: G. A. Feldhamer, et al. (Eds.), Wild Mammals of North America: Biology, Management, and Conservation, John Hopkins University Press, Baltimore, Maryland. pp. 482-510.

Parker G.R., Morton L.D. (1978) The estimation of winter forage and use by moose on clearcuts in northcentral Newfoundland. Journal of Range Management 31:300-304.

Parker K.L., Robbins C.T., Hanley T.A. (1984) Energy expenditures for locomotion by mule deer and elk. Journal of Wildlife Management 48:474-488.

Paul T.W. (2009) Game transplants in Alaska. Technical Bulletin No. 4, 2nd Ed., Alaska Department of Fish and Game, Juneau, AK. pp. 150.

Paulson D.R. (1995) Black-bellied Plover (Pluvialis squatarola), No. 186, in: A. Poole and F. Gill (Eds.), The Birds of North America, Academy of Natural Sciences, Philadelphia, PA.

Paxinos E.E., James H.F., Olson S.L., Sorenson M.D., Jackson J., Fleischer R.C. (2002) mtDNA from fossils reveals a radiation of Hawaiian geese recently derived from the Canada goose (Branta canadensis). Proc. Nation. Acad. Sci. 99:1399-1404.

Pearce J.M., Talbot S.L., Peterson M.R., Rearick J.R. (2005) Limited genetic differentiation among breeding, molting, and wintering groups of the threatened Steller's eider: the role of contemporary and historic factors. Conservation Genetics 6:743-757.

Pearce J.M., Talbot S.L., Pierson B.J., Petersen M.R., Scribner K.T., Dickson D.L., Mosbech A. (2004) Lack of spatial genetic structure among nesting and wintering king eiders. Condor 106:229-240.

Pebble Partnership. (2011) Report on Terrestrial Wildlife and Habitats. http://www.pebblepartnership.com/environment/data-releases.

Peek J.M. (1986) A review of wildlife management Prentice-Hall, Englewood Cliffs, New Jersey.

Peek J.M. (2007) Habitat relationships, in: A. W. Franzmann and C. C. Schwartz (Eds.), Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 351-376.

Person D.K. (2001) Wolves, deer and logging: Population vitality and predator-prey dynamics in a disturbed insular landscape, University of Alaska, Fairbanks.

Person D.K., Kirchhoff M.D., Van Ballenberghe V., Iverson G.C., Grossman E. (1996) The Alexander Archipelago wolf: a conservation assessment. PNW-GTR-384., USDA Forest Service Gen. Tech. Rep. pp. 42pp.

Person D.K., Russell A.L. (2008) Correlates of mortality in an exploited wolf population. Journal of Wildlife Management 72:1540-1549.

Person D.K., Russell A.L. (2009) Reproduction and den site selection by wolves in a disturbed landscape. Northwest Science 83.

Petersen M.R. (1981) Populations, feeding ecology and molt of Steller's eiders. Condor 83:256-262.

Petersen M.R., Schmutz J.A., Rockwell R.F. (1994) Emperor Goose (Chen canagica), No. 97, in: A. Poole and F. Gill (Eds.), The Birds of North America, Academy of Natural Sciences, Philadelphia, PA.

Petersen M.R., Weir D.N., Dick M.H. (1991) Birds of the Kilbuck and Ahklun Mountain Region, Alaska. North American Fauna No. 76, U.S. Fish and Wildlife Service.

Peterson R.L. (1952) A review of the living representatives of the genus Alces. Contributions to the Royal Ontario Museum of Zoology and Paleontology 34:1-30.

Peterson R.L. (1955) North American moose University of Toronto Press, Toronto, Ontario, Canada.

Peterson R.O., Woolington J.D., Bailey T.N. (1984) Wolves of the Kenai Peninsula, Alaska. Wildlife Monographs 88:1-52.

Peterson S.R., Ellarson R.S. (1977) Food habits of oldsquaws wintering on Lake Michigan. Wilson Bulletin 89:81-91.

Phillips L.M., Powell A.N., Rexstad E.A. (2006) Large-scale movements and habitat characteristics of King Eiders throughout the nonbreeding period. Condor 108:887-900.

Phillips R.L., Burg W.E., Sniff D.B. (1973) Moose movement patterns and range use in northeastern Minnesota. Journal of Wildlife Management 37:266-278.

Piersma T., Gill R.E., De Goeij P., Dekinga A., Shepherd M.L., Ruthrauff D., Tibbitts L. (2006) Shorebird avoidance of nearshore feeding and roosting areas at night correlates with presence of a nocturnal avian predator. Wader Study Group Bulletin 109:73-76.

Pimlott D.H. (1959) Reproduction and productivity of Newfoundland moose. Journal of Wildlife Management 23:381-401.

Pitelka F.A. (1959) Numbers, breeding schedule, and territoriality in Pectoral Sandpipers of Northern Alaska. Condor 61:233-264.

Platte R.M., Butler W.I. (1995) Water bird abundance and distribution in the Bristol Bay Region, Alaska. Unpublished, U.S. Fish and Wildlife Service. pp. 28.

Pruitt W.O. (1959) Snow as a factor in the winter ecology of the barren ground caribou. Arctic 12:159-179.

Quammen M.L. (1984) Predation by shorebirds, fish and crabs on invertebrates in intertidal mudflats: an experimental test. Ecology 65:529-537.

Quinn T.P. (2004) The behavior and ecology of Pacific salmon and trout University of Washington Press, Seattle, WA.

Quinn T.P., Carlson S.M., Gende S.M., Rich H.B.J. (2009) Transportation of Pacific salmon carcasses from streams to riparian forests by bears. Can. J. Zool. 87:195-203.

Quinn T.P., Wetzel L., Bishop S., Overberg K., Rogers D.E. (2001) Influence of breeding habitat on bear predation and age at maturity and sexual dimorphism of sockeye salmon populations. Can. J. Zool. 79:1782-1793.

Ramsay M.A., Stirling I. (1988) Reproductive biology and ecology of female polar bears (Ursus maritimus). Journal of Zoology 214:601-633.

Reed A., Ward D., Derksen D.V., Sedinger J.S. (1998) Brant (Branta bernicla), No. 337. The Birds of North America:32.

Regelin W.L., Schwartz C.C., Franzmann A.W. (1985) Seasonal energy metabolism of adult moose. Journal of Wildlife Management 49:394-396.

Reimchen T.E. (2000) Some ecological and evolutionary aspects of bear-salmon interactions in coastal British Columbia. Canadian Journal of Zoology 78:448-457.

Renecker L.A., Hudson R.J. (1986) Seasonal energy expenditures and thermoregulatory responses of moose. Canadian Journal of Zoology 64:322-327.

Renecker L.A., Hudson R.J. (1989) Ecological metabolism of moose in aspen-dominated forests, central Alberta. Canadian Journal of Zoology 67:1923-1928.

Renecker L.A., Schwartz C.C. (2007) Food habits and feeding behavior, in: A. W. Franzmann and C. C. Schwartz (Eds.), Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 403-440.

Reynolds H.V. (1976) North slope grizzly bear studies. Final Report, Federal Aid in Wildlife Research Project W-17-6 and W-17-7, Alaska Department of Fish and Game. pp. 20.

Rich T.D., Beardmore C.J., Berlanga H., Blancher P.J., Bradstreet M.S.W., Butcher G.S., Demarest D.W., Dunn E.H., Hunter W.C., Inigo-Elias E.E., Kennedy J.A., Martell A.M., Panjabi A.O., Pashley D.N., Rosenberg K.V., Rustay C.M., Wendt J.S., Will T.C. (2004) Partners in Flight North American Landbird Conservation Plan Cornell Lab of Ornithology, Ithaca, NY.

Risenhoover K.L. (1986) Winter activity patterns of moose in interior Alaska. Journal of Wildlife Management 50:727-734.

Risenhoover K.L. (1989) Composition and quality of moose winter diets in interior Alaska. Journal of Wildlife Management 53:568-577.

Ritchie R.J. (1982) Investigations of Bald Eagles, Tanana River, Alaska, 1977-80, in: W. N. Ladd and P. F. Schempf (Eds.), Raptor management and biology in Alaska and Western Canada: proceedings of a symposium and workshop held February 17-20, 1981, U.S. Fish and Wildlife Service, Anchorage, AK. pp. 55-67.

Ritchie R.J., Ambrose R.E. (1987) Winter records of Bald Eagles, Haliaeetus leucocephalus, in Interior Alaska. Canadian Field-Naturalist 101:86-87.

Ritchie R.J., Ambrose R.E. (1996) Distribution and population status of Bald Eagles in Interior Alaska. Arctic 49:120-128.

Robards F.C., King J.G. (1966) Nesting and productivity of Bald Eagles in Southeast Alaska-1966, U.S. Fish and Wildlife Service, Juneau, AK.

151

Robbins C.T., Fortin J.K., Rode K.D., Farley S.D., Shipley L.A., Felicetti L.A. (2007) Optimizing protein intake as a foraging strategy to maximize mass gain in an omnivore. Oikos 116:1675-1682.

Robbins C.T., Hanley T.A., Hagerman A.E., Hjeljord O., Baker D.L., Schwartz C.C., Mautz W.W. (1987) Role of tannins in defending plants against ruminants: reduction in protein availability. Ecology 68:98-107.

Robertson G.J., Goudie R.I. (1999) Harlequin Duck (Histrionicus histrionicus) No. 466, in: A. Poole (Ed.), The Birds of North America, Cornell Lab of Ornithology, Ithaca, NY.

Rode K.D., Farley S.D., Fortin J.K., Robbins C.T. (2007) Nutritional consequences of experimentally introduced tourism in brown bears. Journal of Wildlife Management 71:929-939.

Rode K.D., Farley S.D., Robbins C.T. (2006a) Behavioral responses of brown bears mediate nutritional impacts of experimentally introduced tourism. Biol. Conserv. 133:70-80.

Rode K.D., Farley S.D., Robbins C.T. (2006b) Sexual dimorphism, reproductive strategy, and human activities determine resource use by brown bears. Ecology 87:2636-2646.

Rothman R.J., Mech L.D. (1979) Scent-marking in lone wolves and newly formed pairs. Animal Behavior 27:750-760.

Rubega M.A., Schamel D., Tracy D.M. (2000) Red-necked Phalarope (Phalorupus lobatus), No. 538, in: A. Poole and F. Gill (Eds.), The Birds of North America, Academy of Natural Sciences, Philadelphia, PA.

Ruggerone G.T., Peterman R.M., Dorner B., Meyers K.W. (2010) Magnitude and trends in abundance of hatchery and wild pink salmon, chum salmon, and sockeye salmon in the North Pacific Ocean. Marine and Coastal Fisheries 2:306-328.

Ruthrauff D.R., Tibbitts T.L., Gill R.E., Handel C.M. (2007) Inventory of montane-nesting birds in Katmai and Lake Clark National Parks and Preserves. Unpublished Final Report for National Park Service, U.S. Geological Survey, Alaska Science Center, Anchorage, AK.

Saether B.E. (1987) Patterns and processes in the population dynamics of the Scandinavian moose (Alces alces): some suggestions. Swedish Wildlife Research Supplement 1:525-537.

Salomone P., Morstad S., Sands T., Jones M., Baker T., Buck G., West F., Kreig T. (2011) 2010 Bristol Bay Area annual management report., Fishery Management Report No. 11-23, Alaska Department of Fish and Game, Juneau, AK. pp. 138 pgs.

Salyer J.C., Lagler K.F. (1940) The food and habits of the American merganser during winter in Michigan, considered in relation to fish management. J. Wildl. Manage. 4:186-219.

Sanchez M.I., Green A.J., Alejandre R. (2006) Shorebird predation affects density, biomass, and size distribution of benthic chironomids in salt pans: an exclosure experiment. Journal of the North American Benthological Society 25:9-18.

Sanger G.A., Jones R.D. (1984) Winter feeding ecology and trophic relationships of oldsquaws and white-winged scoters on Kachemak Bay, Alaska, in: D.N. Nettleship, et al. (Eds.), Marine birds: their feeding ecology and commercial fisheries relationships, Canadian Wildl. Serv. Spec. Publ., Ottawa. pp. 20-28.

Savage S. (1993) Bald Eagle nesting and productivity - Katmai National Park 1993, National Park Service, Katmai National Park and Preserve, King Salmon, AK.

Savage S. (1997) Bald Eagle nesting and productivity - Katmai National Park 1991-1997, Alaska Bird Conference 1997, Anchorage, AK.

152

Savage S. (personal communication) Telephone conversation between S. Savage, USFWS and Maureen De Zeeuw, USFWS dated 09/14/2011.

Savage S., Hodges J.I. (2006) Bald Eagle survey - Pacific coast of the Alaska Peninsula, Alaska, Spring 2005, U.S. Fish and Wildlife Service, King Salmon, AK.

Savage S.E., Tibbitts T.L. (In prep) Inventory of breeding birds on lowlands of the Alaska Peninsula: Results of surveys from the Naknek River to Port Moller, 2004-2007.

Schamber J.L., Flint P.L., Powell A.N. (2010) Patterns of use and distribution of King Eiders and Black Scoters during the annual cycle in Northeastern Bristol Bay, Alaska. Marine Biology 157:2169-2176.

Schempf P.F. (1989) Raptors in Alaska, in: B. G. Pendleton (Ed.), Proceedings of the Western Raptor Management Symposium and Workshop, National Wildlife Federation Scientific and Technical Series No. 12. pp. 144-154.

Schichnes D., Chythlook M. (1988) Wild resource use in Manokotak, Southwest Alaska. Technical Paper No. 152, Alaska Department of Fish and Game, Division of Subsistence.

Schichnes D., Chythlook M. (1991) Contemporary use of fish and wildlife in Ekwok, Koliganek and New Stuyahok, Alaska, in: D. o. Subsistence (Ed.), Technical Paper No. 185., Alaska Dept. of Fish and Game, Juneau. pp. 243pp + appendices.

Schindler D.E., Leavitt P.R., Brock C.S., Johnson S.P., Quay P.D. (2005) Marine-derived nutrients, commercial fisheries, and production of salmon and lake algae in Alaska. Ecology 86:3225-3231.

Schoen J., Lentfer J.W., Beier L. (1986) Differential distribution of brown bears on Admiralty Island, southeast Alaska: a preliminary assessment. Int. Conf. Bear Res. and Manage. 6:1-5.

Schwartz C.C. (1992) Physiological and nutritional adaptations of moose to northern environments. Alces Supplement 1:139-155.

Schwartz C.C. (2007) Reproduction, natality, and growth, in: A. W. Franzmann and C. C. Schwartz (Eds.), Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 141-171.

Schwartz C.C., Bartley B. (1991) Reducing incidental moose mortality: considerations for management. Alces 27:227-231.

Schwartz C.C., Franzmann A.W. (1989) Bears, wolves, moose, and forest succession, some management considerations on the Kenai Peninsula, Alaska. Alces 25:1-10.

Schwartz C.C., Franzmann A.W. (1991) Interrelationship of black bears to moose and forest succession in the northern coniferous forest. Wildlife Monographs 113:3-58.

Schwartz C.C., Hubbert M.E., Franzmann A.W. (1988) Energy requirements of adult moose for winter maintenance. Journal of Wildlife Management 52:26-33.

Schwartz C.C., Hundertmark K.J. (1993) Reproductive characteristics of Alaska moose. Journal of Wildlife Management 57:454-458.

Schwartz C.C., Miller S.D., Haroldson M.A. (2003) Grizzly Bear, in: G. A. Feldhamer, et al. (Eds.), Wild mammals of North America: Biology, management, and conservation, John Hopkins University Press, Baltimore, Maryland. pp. 556-582.

Schwartz C.C., Regelin W.L., Franzmann A.W. (1987) Protein digestion in moose. Journal of Wildlife Management 51:352-357.

Schwartz C.C., Renecker L.A. (2007) Nutrition and energetics, in: A. W. Franzmann and C. C. Schwartz (Eds.), Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 440-478.

153

Scribner K.T., Talbot S.L., Pearce J.M., Pierson B.J., Bollinger K.S., Derksen D.V. (2003) Phylogeography of Canada geese (Branta canadensis) in western North America. Auk 120:889-907.

Sedinger J.S., Bollinger K.S. (1987) Autumn staging of cackling Canada geese on the Alaska Peninsula. Wildfowl 38:13-18.

Seip D.R. (1992) Factors limiting woodland caribou populations and their interrelationships with wolves and moose in southeastern British Columbia. Can. J. Zool. 70:1494-1503.

Selkowitz D.J., Stehman S.V. (2011) Thematic accuracy of the National Land Cover Database (NLCD) 2001 land cover for Alaska. Remote Sensing of Environment 115:1401-1407.

Selkregg L.L.e. (1976) Alaska regional profiles: southwest region University of Alaska, Arctic Environ. Info. and Data Ctr, Anchorage.

Senner S.E. (1979) An evaluation of the Copper River Delta as a critical habitat for migratory shorebirds. Studies in Avian Biology 2:131-145.

Senner S.E., West G.C., Norton D.W. (1981) The spring migration of Western Sandpipers and Dunlins in Southcentral Alaska: numbers, timing and sex ratio. Journal of Field Ornithology 52:271-284.

Servheen C. (1996) Grizzly bear recovery plan, U.S. Fish and Wildlife Service, Missoula, MT.

Servheen G., Lyon L.J. (1989) Habitat use by woodland caribou in the Selkirk Mountains. Journal of Wildlife Management 53:230-237.

Shelford V.E. (1963) The ecology of North America University of Illinois Press, Urbana, IL.

Sherrod S.K., White C.M., Williamson F.S.L. (1976) Biology of the Bald Eagle on Amchitka Island, Alaska. Living Bird 15:143-182.

Sidle W.B., Suring L.H. (1986) Management indicator species for the national forest lands in Alaska, USDA Forest Service Alaska Region, Technical Publication R 10-TP-2.

Sidle W.B., Suring L.H., Hodges J.I. (1986) The Bald Eagle in Southeast Alaska, USDA Forest Service Alaska Region, Wildlife and Fish Habitat Management Note 11. pp. 29.

Singer F.J., Dalle-Molle J. (1985) The Denali ungulate-predator system. Alces 21:339-358.

Skeel M.A., Mallory E.P. (1996) Whimbrel (Numenius phaeopus), No. 219, in: A. Poole and F. Gill (Eds.), The Birds of North America, Academy of Natural Sciences, Philadelphia, PA.

Skoog R.O. (1968) Ecology of caribou (Rangifer tarandus granti) in Alaska, University of California, Berkeley, CA. pp. 699.

Smith T.S., Partridge S.T. (2004) Dynamics of intertidal foraging by coastal brown bears in southwestern Alaska. Journal of Wildlife Management 68:233-240.

Spencer D.I., Hakala J.B. (1964) Moose and fire on the Kenai. Proceedings of Tall Timbers Fire Ecology Conference 3:11-33.

Spencer D.L., Chatelaine E.F. (1953) Progress in the management of the moose in south central Alaska. Transactions of the North American Wildlife Conference 18:539-552.

Spencer P. (2006) Monitoring landscape processes in Southwest Alaska using MODIS, U.S. Fish and Wildlife Service Region 7 Biologist Conference.

Spencer P. (personal communication) Email from P. Spencer (NPS/retired) to Phil Brna (USFWS) dated August 31, 2011

Stalmaster M.V. (1981) Ecological energetics and foraging behavior of wintering Bald Eagles, Utah State University, Logan, UT. pp. 157.

Stalmaster M.V. (1987) The Bald Eagle Universe Books, New York, NY.

Stalmaster M.V., Gessaman J.A. (1982) Food consumption and energy requirements of captive Bald Eagles. Journal of Wildlife Management 46:646-654.

Stalmaster M.V., Gessaman J.A. (1984) Ecological energetics and foraging behavior of overwintering Bald Eagles. Ecological Monographs 54:407-428.

Stalmaster M.V., Knight R.L., Holder B.L., Anderson R.J. (1985) Bald Eagles, in: E. R. Brown (Ed.), Management of wildlife and fish habitats in forests of western Oregon and Washington, U.S. Forest Service Pacific Northwest Region Publication R6-F&WL-192-1985. pp. 269-290.

Stauffer D.F., Best L.B. (1980) Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. Journal of Wildlife Management 44:1-15.

Stehn R., Platte R.M., Anderson P.D. (2010) Pacific Black Scoter Breeding Survey. Unpublished progress report, Sea Duck Joint Venture, Project #96, U.S. Fish and Wildlife Service, Anchorage, AK. pp. 6.

Stehn R., Platte R.M., Anderson P.D., Broerman F., Moran T., Sowl K., Richardson K. (2006) Monitoring Black Scoter populations in Alaska, 2005. Unpublished, U.S. Fish and Wildlife Service, Alaska. pp. 44.

Steidl R.J., Kozie K.D., Anthony R.G. (1997) Reproductive success of Bald Eagles in Interior Alaska. Journal of Wildlife Management 61:1313-1321.

Stephens D.W., Krebs J.R. (1986) Foraging Theory Princeton University Press, Princeton, N.J.

Stephenson T.R., Van Ballenberghe V., Peek J.M., MacCracken J.G. (2006) Spatio-temporal constraints on moose habitat and carrying capacity in coastal Alaska: vegetation succession and climate. Rangeland Ecology & Management 59:359-372.

Stinson C.H. (1980) Flocking and predator avoidance: models of flocking and observations on the spatial dispersion of foraging winter shorebirds (Charadrii). Oikos 34:35-43.

Stinson D.W., Watson J.W., McAllister K.R. (2001) Washington State status report for the Bald Eagle, Washington Department of Fish and Wildlife, Olympia, WA.

Stout J.H., Trust K.A. (2002) Elemental and organochlorine residues in Bald eagles from Adak Island, Alaska. Journal of Wildlife Diseases 38:511-517.

Straty R. (1977) Current patterns and distribution of river waters in Inner Bristol Bay, Alaska. NOAA Technical Report NMFS SSRF-713

U.S. Department of Commerce, NOAA/NMFS, Washington, D.C. pp. 13.

Stroud D.A., Baker A., Blanco D.E., Davidson N.C., Delany S., Ganter B., Gill R.E., Gonzalez P., Haanstra L., Morrison R.I.G., Piersma T., Scott D.A., Thorup O., West R., Wilson J., Zockler C. (2006) The conservation and populations status of the world's waders at the turn of the millennium, in: G. C. Boere, et al. (Eds.), Waterbirds around the world, The Stationery Office, Scotland Ltd., Edinburgh, U.K. pp. 643-648.

Suring L.H. (2010) Habitat relationships of Bald Eagles in Alaska, in: B. A. Wright and P. Schempf (Eds.), Bald Eagles in Alaska, Hancock House Publishers, Surrey, British Columbia, Canada. pp. 106-116.

Suydam R.S. (2000) King Eider (Somateria spectabilis), No. 491, in: A. Poole and F. Gill (Eds.), The Birds of North America, Cornell Lab of Ornithology, Ithaca, NY.

Swaim M. (personal communication) Email from M. Swaim, USFWS to Maureen De Zeeuw, USFWS dated 08/18/2011.

Szepanski M.M., Ben-David M., Van Ballenberghe V. (1999) Assessment of anadromous salmon resources in the diet of the Alexander Archipelago wolf using stable isotope analysis. Oecologia 120:327-335.

Takimoto G., Iwata T., Murakami M. (2002) Seasonal subsidy stabilizes food web dynamics: balance in a heterogeneous landscape. Ecological Research 17:433-439.

Talbot S. (2010) *Vegetation Mapping in Boreal Alaska. Proceedings of the Fifth International Workshop: Conservation of Arctic Flora and Fauna (CAFF) Flora Group.*, in: S. Talbot, et al. (Eds.), *Circumboreal Vegetation Mapping (CBVM) Workshop, Helsinki, Finland, November 3-6th, 2008*, CAFF International Secretariat, CAFF Flora Expert Group (CFG).

Taverner P.A. (1934) *Birds of Canada Can. Dept. Mines, Ottawa.*

Taylor A.R., Lanctot R.B., Powell A.N., Kendall S.J., Nigro D. (2011) *Residence time and movement patterns of postbreeding shorebirds on Alaska's northern coast. Condor In press.*

Telfer E.S., Kelsall J.P. (1984) *Adaptation of some large North American mammals for survival in snow. Ecology 65:1828-1834.*

Testa J.W. (2004) *Population dynamics and life history trade-offs of moose (Alces alces) in south-central Alaska. Ecology 85:1439-1452.*

Testa J.W., Becker E.F., Lee G.R. (2000) *Movements of female moose in relation to birth and death of calves. Alces 36:155-162.*

The Nature Conservancy in Alaska. (2004) *Alaska Peninsula and Bristol Bay basin ecoregional assessment, The Nature Conservancy, Anchorage, AK. pp. 132.*

Theberge J.B. (1969) *Observations of wolves at a rendezvous site in Algonquin Park. Canadian Field-Naturalist 83:122-128.*

Thompson I.D., Euler D.J. (1987) *Moose habitat in Ontario: a decade of change in perception. Swedish Wildlife Research Supplement 1:181-193.*

Thomson R. (1991) *Crown land wildlife habitat protection and development projects, northwest portion of central region, Alberta Department of Forest, Lands and Wildlife, Edmonton, Alberta, Canada.*

Thurber J.M., Peterson R.O., Drummer T.D., Thomasma S.A. (1994) *Gray wolf response to refuge boundaries and roads in Alaska. Wildlife Society Bulletin 22:61-68.*

Tibbetts T.L. (personal communication) *Telephone conversation between T.L. Tibbetts, USGS and S. Savage, USFWS dated September 2011.*

Timm D.E. (1977) *Waterfowl*, in: E. G. Klinkhart and J. W. Schoen (Eds.), *A fish and wildlife resource inventory of the Alaska Peninsula, Aleutian Islands and Bristol Bay areas, Vol. 1 Wildlife. Unpublished report to the Office of Coastal Zone Management, NOAA, Alaska Department of Fish and Game, Juneau, AK. pp. 200-266.*

Timmerman H.R., Buss M.E. (2007) *Population and harvest management*, in: A. W. Franzmann and C. C. Schwartz (Eds.), *Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 559-616.*

Tollefson T.N., Matt C.A., Meehan J., Robbins C.T. (2005) *Research Notes: Quantifying spatiotemporal overlap of Alaskan brown bears and people. Journal of Wildlife Management 69:810-817.*

Troyer W.A., Hensel R.J. (1964) *Structure and distribution of a Kodiak bear population. Journal of Wildlife Management 28:769-772.*

Underhill L.G., Prys-Jones R.P., Syroechkovski E.E., Groen N.M., Karpov V., Lappo H.G., Van Roomen M.W.J., Rybkin A., Schekkerman H., Spiekman H., Summers R.W. (1993) *Breeding of waders (Charadrii) and Brent Geese Branta bernicla bernicla at Pronchishcheva Lake, northeastern Taimyr, Russia, in a peak and a decreasing lemming year. Ibis 135:277-292.*

156

USFS. (2008) Tongass National Forest land and resource management plan, U.S. Forest Service Alaska Region Publication R10-MB-603b.

USFWS. (1976) A biological resource assessment of the Bristol Bay OCS. Unpublished, U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, AK. pp. 100.

USFWS. (1999) Population status and trends of sea ducks in Alaska. Unpublished, U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, AK. pp. 137.

USFWS. (2002) Steller's Eider Recovery Plan. Unpublished, U.S. Fish and Wildlife Service, Fairbanks, AK. pp. 27.

USFWS. (2008) Birds recorded on the Togiak National Wildlife Refuge. http://togiak.fws.gov/birds_spp.htm, U.S. Fish and Wildlife Service, Togiak National Wildlife Refuge, Dillingham, AK.

USFWS. (2009a) Bald Eagle natural history and sensitivity to human activity information, U.S. Fish and Wildlife Service, Anchorage, AK.

USFWS. (2009b) Comprehensive Conservation Plan: Togiak National Wildlife Refuge, U.S. Fish and Wildlife Service, Region 7, Anchorage, AK.

USFWS. (2010a) 2010 Pacific Flyway data book. Unpublished, U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Portland, OR. pp. 105.

USFWS. (2010b) Birds of the Alaska Peninsula and Becharof National Wildlife Refuges, U.S. Fish and Wildlife Service.

USFWS. (2011) Species Profile for Gray Wolf (Canis lupus), U.S. Fish and Wildlife Service.

USFWS, US Department of Commerce Census Bureau. (2006) 2006 National survey of fishing, hunting, and wildlife-associated recreation.

USGS. (2011) North American Breeding Bird Survey, U.S. Geological Service.

USGS Bird Banding Lab. (2011) Online: http://www.pwrc.usgs.gov/bbl/, U.S. Geological Survey.

Valkenburg P. (2001) Stumbling towards enlightenment: understanding caribou dynamics. Alces 37:457-474.

Valkenburg P., Sellers R.A., Squibb R.C., Woolington J.D., Aderman A.R., Dale B.W. (2003) Population dynamics of caribou herds in southwestern Alaska. Rangifer Special Issue 14:131-142.

Van Ballenberghe V. (1977) Migratory behavior of moose in southcentral Alaska, in: T. J. Peterle (Ed.), XIIIth International Congress of Game Biologists, Wildlife Management Institute, Washington, D.C. pp. 103-109.

Van Ballenberghe V., Ballard W.B. (2007) Population dynamics, in: A. W. Franzmann and C. C. Schwartz (Eds.), Ecology and management of the North American moose, University Press of Colorado, Boulder, Colorado. pp. 223-246.

Van Ballenberghe V., Miquelle D.G. (1990) Activity of moose during spring and summer in interior Alaska. Journal of Wildlife Management 54:391-396.

Van Ballenberghe V., Miquelle D.G. (1993) Mating in moose: timing, behavior, and male access patterns. Canadian Journal of Zoology 71:1687-1690.

Van Ballenberghe V., Miquelle D.G., MacCracken J.G. (1989) Heavy utilization of woody plants by moose during summer at Denali National Park, Alaska. Alces 25:31-35.

Van Daele L.J., Barnes V.G.J., Smith R.B. (1990) Denning characteristics of brown bears on Kodiak Island, Alaska. Int. Conf. Bear Res. and Manage. 8:257-267.

Vermeer K. (1981) Food and populations of surf scoters in British Columbia. Wildfowl 32:107-116.

Vermeer K. (1982) Food and distribution of three Bucephala species in British Columbia waters. Wildfowl 33:22-30.

Vermeer K. (1983) Diet of the harlequin duck in the Strait of Georgia, British Columbia. Murrelet 64:54-57.

Vermeer K., Levings C.D. (1977) Populations, biomass, and food habits of ducks on the Fraser Delta intertidal area, British Columbia. Wildfowl 28:49-60.

Viereck L.A., Dyrness C.T. (1980) A preliminary classification system for vegetation in Alaska. General Technical Report, PNW-106, U.S. Forest Service, Washington, D.C. pp. 38.

Walsh P. (2011) Personal communication from Supervisory Biologist, Togiak National Wildlife Refuge, to Ann Rappoport, U.S. Fish and Wildlife Service, August 17, 2011.

Walsh P., Reynolds J., Collins G., Russell B., Winfree M., Denton J. (2010) Application of a double-observer aerial line-transect method to estimate brown bear population density in southwestern Alaska. Journal of Fish and Wildlife Management 1:47-58.

Ward D.H., Dau C.P., Tibbitts T.L., Sedinger J.S., Anderson B.A., Hines J.E. (2009) Change in abundance of Pacific brant wintering in Alaska: Evidence of a climate change? . Arctic 62:301-311.

Warnock N.D., Gill R.E. (1996) Dunlin (Calidris alpina), No. 203, in: A. Poole and F. Gill (Eds.), The Birds of North America, Academy of Natural Sciences, Philadelphia, PA.

Watts D. (personal communication) Email from D. Watts (USFWS) to Phil Brna (USFWS) dated 08/23/2011.

Watts D.E., Butler L.G., Dale B.W., Cox R.D. (2010) The Ilnik wolf Canis lupus pack: use of marine mammals and offshore sea ice. Wildlife Biology 16:144-149.

Weaver J.L. (1994) Ecology of wolf predation admidst high ungulate diversity in Jasper National Park, Alberta, University of Montana, Missoula.

Weckworth B.V., Talbot S., Sage G.K., Person D.K., Cook J. (2005) A Signal for Independent Coastal and Continental histories among North American wolves. Molecular Ecology 14:917-931.

Weir J.N., Mahoney S.P., McLaren B., Ferguson S.H. (2007) Effects of mine development on woodland caribou Rangifer tarandus distribution. Wildlife Biology 13:66-74.

Weixelman D.A., Bowyer R.T., Van Ballenberghe V. (1998) Diet selection by Alaskan moose during winter: effects of fire and forest succession. Alces 34:213-238.

Welch L.J. (1994) Contaminant burdens and reproductive rates of Bald Eagles breeding in Maine, University of Maine, Orono, Maine.

Wentworth C. (2007) Subsistence migratory bird harvest survey: Bristol Bay 2001-2005. Unpublished, U.S. Fish and Wildlife Service, Anchorage, AK. pp. 27.

Western Hemisphere Shorebird Reserve Network. (2011) Online: http://www.whsrn.org/western-hemisphere-shorebird-reserve-network.

White H.C. (1957) Food and natural history of mergansers on salmon waters in the Maritime provinces of Canada. Bull. Fish. Res. Board Canada 116.

Whitten K.R. (1995) Antler loss and udder distension in relation to parturition in caribou. Journal of Wildlife Management 59:273-277.

Whitten K.R., Garner G.W., Mauer F.J., Harris R.B. (1992) Productivity and early calf survival in the Porcupine Caribou Herd. Journal of Wildlife Management 56:201-212.

Wiebe K.L., Martin K. (1998) Seasonal use by birds of stream-side riparian habitat in coniferous forest of northcentral British Columbia. Ecography 21:124-134.

Wilder J.M., Debruyn T.D., Smith T.S., Southwould A. (2007) Systematic collection of bear-human interaction information for Alaska's national parks. Ursus 18:209-216.

Wilk R.J. (1988) Distribution, abundance, population structure and productivity of Tundra Swans in Bristol Bay, Alaska. Arctic 41:288-292.

Williamson F.S.L., Peyton L.J. (1962) Faunal relationships of birds in the Iliamna Lake area, Alaska. Biological Papers of the University of Alaska, #5. pp. 73.

Willson M.F., Armstrong R.H. (1998) Intertidal foraging for Pacific Sand-lance, Ammodytes hexapterus, by birds. Canadian Field-Naturalist 112.

Willson M.F., Gende S.M., Marston B.H. (1998) Fishes and the forest: expanding perspectives on fish-wildlife interactions. Bioscience 48:455-462.

Willson M.F., Halupka K.C. (1995) Anadromous fish as keystone species in vertebrate communities. Conservation Biology 9:489-497.

Wilson W.H. (1989) Predation and the mediation of intraspecific competition in an infaunal community in the Bay of Fundy. Journal of Experimental Marine Biology and Ecology 132:221-245.

Wipfli M.S., Hudson J.P., Chaloner D.T., Caouette J.P. (1999) Influence of salmon spawner densities on stream productivity in Southeast Alaska. Can. J. Fish. Aquat. Sci. 56:1600-1611.

Witter L. (personal communication) Email from B. Mangipane, NPS to Phil Brna, USFWS dated 08/29/2011.

Wolfe R.J. (1991) Trapping in Alaska communities with mixed, subsistence-cash economies, Alaska Department of Fish and Game, Division of Subsistence, Juneau, AK.

Wolfe R.J., Paige A.W. (1995) The subsistence harvest of Black Brant, Emperor Geese, and Eider Ducks in Alaska. Technical Paper No. 234, Alaska Department of Fish and Game, Division of Subsistence, Juneau, AK. pp. 39.

Wolfe R.J., Paige A.W., Scott C.L. (1990) The subsistence harvest of migratory birds in Alaska. Technical Paper No. 197, Alaska Department of Fish and Game, Division of Subsistence, Juneau, AK. pp. 86.

Wong D., Wentworth C. (1999) Subsistence waterfowl harvest survey, Bristol Bay 1995-1998. Unpublished, U.S. Fish and Wildlife Service, Anchorage, AK. pp. 14.

Wood C.C. (1987a) Predation of juvenile Pacific salmon by the common merganser (Mergus merganser) on Eastern Vancouver Island I: predation during the seaward migration. Can. J. Fish. Aquat. Sci. 44:941-949.

Wood C.C. (1987b) Predation of juvenile Pacific salmon by the common merganser (Mergus merganser) on eastern Vancouver Island II: Predation of stream-resident juvenile salmon by merganser broods. Can. J. Fish. Aquat. Sci 44:950-959.

Woolington J.D. (2004) Unit 17 moose management report, in: C. Brown (Ed.), Moose management report of survey and inventory activities: 1 July 2001 - 30 June 2003, Alaska Department of Fish and Game, Juneau, AK. pp. 246-266.

Woolington J.D. (2008) Unit 17 moose management report, in: P. Harper (Ed.), Moose management report of survey and inventory activities 1 July 2005-30 June 2007, Alaska Department of Fish and Game, Juneau, AK. pp. 246-268.

Woolington J.D. (2009a) Mulchatna caribou management report, Units 9B, 17, 18 south, 19A & 19B, in: P. Harper (Ed.), Caribou management report of survey and inventory activities 1 July 2006-1 July 2008, Alaska Department of Fish and Game, Juneau, AK. pp. 11-31.

Woolington J.D. (2009b) Unit 17 wolf management report, in: P. Harper (Ed.), Wolf management report of survey and inventory activities 1 July 2005-30 June 2008, Alaska Department of Fish and Game, Juneau, AK. pp. 121-127.

Wright B.A., Schempf P. (2010) Introduction, in: B. A. Wright and P. Schempf (Eds.), Bald Eagles in Alaska, Hancock House Publishers, Surrey, British Columbia, Canada. pp. 8-18.

Wright J.M. (2010) Bald Eagles in western Alaska, in: B. A. Wright and P. Schempf (Eds.), Bald Eagles in Alaska, Hancock House Publishers, Surrey, British Columbia, Canada. pp. 251-257.

Wright J.M., Morris J.M., Schroeder R. (1985) Bristol Bay regional subsistence profile. Technical Paper No. 114, Alaska Department of Fish and Game, Division of Subsistence, Dillingham, AK. pp. 93pp. + appendices.

Ydenberg R.C., Butler R.W., Lank D.B., Smith B.D., Ireland J. (2004) Western Sandpipers have altered migration tactics as Peregrine Falcon populations have recovered. Proceedings of the Royal Society B 271:1263-1269.

Yohannes E., Valcu M., Lee R.W., Kempenaers B. (2010) Resource use for reproduction depends on spring arrival time and wintering area in an arctic breeding shorebird. Journal of Avian Biology 41:580-590.

Zhang Y., Negishi J.N., Richardson J.S., Kolodziejczyk R. (2003) Impacts of marine-derived nutrients on stream ecosystem functioning. Proceedings of the Royal Society B 270:211-212.

Zwiefelhofer D. (2007) Comparison of Bald Eagle (Haliaeetus leucocephalus) nesting and productivity at Kodiak National Wildlife Refuge, Alaska, 1963-2002. Journal of Raptor Research 41:1-9.

Zwiefelhofer D. (personal communication) Email from D. Zwiefelhofer, USFWS (retired) to Maureen De Zeeuw, USFWS dated 08/19/2011.